HISTORY, SCIENCE AND SOCIETY IN THE INDIAN CONTEXT

Edited by

ARUN KUMAR BISWAS

The Asiatic Society
1, Park Street, Calcutta - 16

ABOUT THE BOOK

The Asiatic Society, Calcutta, has been conducting, every year, intensive short courses in the area of history of science. The present monograph HISTORY, SCIENCE AND SOCIETY IN THE INDIAN CONTEXT is a compilation of some of the lectures delivered by experts on various facets of the broad theme.

23 articles contributed by 20 authors have been classified in this book under six sections : general observations, science in the ancient world, S & T in pre-modern India, salient features in modern science, S & T in post-independence India and lastly, social factors in the promotion of S & T.

An attempt has been made to resuscitate the subject of history of science and broaden it to include philosophy, sociology and *planning* of S & T in India. It has been emphasized that the studies on history of science should never ignore other aspects of civilization and cultural values, the principle of causality and integration of the history of the past with the planning for future. We hope that the scholars may appreciate this special pedagogic endeavour.

Frontispiece shows Acharyya Jagadis Chandra Bose demonstrating his micro-wave experiments at the Royal Institution, London in 1897 and sixty years later, Calcutta University celebrating its centenary : a spray drier in operation and a zoology laboratory.

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A Collection of Papers

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Dedicated to
The Loving Memory
of
Late Professor Chanchal Kumar Majumdar
(1938-2000)

FOREWORD

The Asiatic Society is pleased to publish *History, Science and Society in the Indian Context,* a multi-authored monograph, as its first contribution of its kind in the 21st century. The Society's forays in the area of Indian science started in the 18th century with the serial publication of *Asiatick Researches* since 1788. After the pioneering works of Joseph Tieffenthaler, W. H. Hunter, H. T. Colebrooke etc., our Society was firmly put on the intellectual map of the world by James Prinsep who not only deciphered the Brahmi script but also established, as documented by Professor Arun Kumar Biswas (Indian Museum Bulletin, Vol. 32,1997, pp. 104-124 and pp. 217-220), the first tradition of multi-scholar collaborative scientific research in India. Pramathanath Bose not only wrote a centennial review on the scientific contributions of our Society (1784-1884), but was also the first Indian to attempt a comprehensive review of Indian history with special emphasis on science and technology.

The Asiatic Society which had done considerable work on history of science and modern science in India, celebrated its bicentenary by establishing a Centre for History of Science in 1986. The Centre worked out a programme of research and teaching, leading to the M.Phil. degree, but this programme could not be implemented on account of various reasons. Instead, the Society introduced in 1994, a one-year certificate course in History of Science which has been offered for several years till 1998, and availed of by a sizeable number of well-qualified students.

Professor Arun Kumar Biswas, the editor of the present monograph, joined this Society in 1995 as its Mahendralal Sircar

Research Professor in History of Science, and proposed three important modifications in the on-going programme. Firstly, it was decided to keep the one-year curriculum on history of science in abeyance and offer in its stead, a ten days' intensive course in which 20-30 experts would deliver a total of 40 lectures of 90 minutes duration each. Secondly, an attempt has been made to resuscitate the subject of history of science in India from its narrow confines and broaden it to include philosophy and sociology in contemporary India. Thirdly, and most importantly, it was suggested that all the lecturers would submit their materials in the form of critical and original articles and that these would be published. Most lecturers have conformed to our suggestions. Professor Arun Kumar Biswas has done his best to edit the available material (23 articles by 20 authors) and to structure this under 6 sections. The intensive course was successfully offered in 1999 and 2000 and we hope to continue our experiments in the future years. As fresh materials become available, this monograph is likely to be revised and upgraded. In the meantime, we strongly believe that this set of articles may be found useful by the students and scholars all over the world as a basis for further studies in the area of history, science and society in the Indian context.

We thank Professor Arun Kumar Biswas who has ably co-ordinated the intensive course and edited this monograph. He has received wonderful support from the experts, lecturers and authors. A special mention may be made of Late Professor Chanchal Kumar Majumdar (1938-2000), who has recently passed away, before he could correct proofs of the two articles that he contributed for the book. The Founder-Director of the S. N. Bose National Centre for Basic Sciences in Calcutta, and an outstanding condensed matter physicist, Professor Majumdar is famous for the so-called Majumdar-Ghosh Hamiltonian, now included in text-books on advanced studies in magnetism. After his formal retirement, he was working as INSA Senior Scientist, Indian Statistical Institute, Calcutta and actively engaged in teaching and research in the fields

of physics and history of science. With a heavy heart and deep sense of gratitude, we dedicate this monograph to the memory of Professor Chanchal Kumar Majumdar.

The Asiatic Society, Calcutta
01.01.2001

MANABENDU BANERJEE
General Secretary

PREFACE

This volume projects a wide-spectrum theme as given in the title, the diverse aspects of which are articulated by a number of competent authors. An attempt has been made to resuscitate the subject of history of science in India from its narrow confines and broaden it to include philosophy and sociology of science as well as planning of science and technology (S&T) in contemporary India.

There is a conventional notion that history is a subject which deals with the past and is not concerned with the future. We however believe that the studies on distant past and recent past provide many valuable clues as to what may happen and what should be done for the immediate future. Planning without a concern for historical background may turn out to be utopian.

The first article seeks to capture the spirit of the monograph. Arun Kumar Biswas explores the majestic heights of two subjects : 'History' and 'Science', and their many similarities. He articulates and defends the concept that the knowledge of history of science and society may be fruitfully utilised in planning of the future of science and society. This exercise however demands a very clear understanding of the desirable goal or goals for the entire civilization. Being a historian himself, Santanu Chacraverti focuses, in the second article, on certain 'uncomfortably epistemological' issues. What is 'historical knowledge'? What is the ultimate truth? How can we eliminate subjectivity altogether and become truly objective? The answer is that we can only try and keep trying. Many historians avoid the term 'objective truth' and settle for Kuhnian paradigms. Social sciences are much more complex and much less predictable and verifiable than the material sciences. A. K. Biswas has argued that this is on account of intrusion of the element of 'consciousness'

which is much more complex than atoms, molecules and material forces.

This monograph is divided into several sections. Following the first section which is devoted to general principles, the second section contains some specific articles on science in ancient and medieval India.

Nupur Dasgupta provides a volume of evidence pointing to a graduated evolution of technology within the peripheries of the Harappan culture through a long preceding period and interacting with several contemporary cultures. C. K. Majumdar deliberates on the physico-chemical ideas in ancient and medieval India and observes that chemical and medical experimentations were extensive in ancient India but the experiments in physics never gained in popularity. Majumdar does not accept the paradigm that the institution of caste provided formidable barrier against diffusion of knowledge and link between experimental skill and theoretical ability. But the facts speak clearly. The medical men (*vaidyas*) who experimented and followed logic were made outcaste by the upper caste Brahmins. Their remarkable contributions on the biological sciences have been documented by Srabani Sen and R. L. Brahmachary. The phenomenon of growth and decay of science in the ancient world is a very fascinating topic. Ashish Lahiri has examined the root causes for the rise and fall of Islamic and Chinese sciences.

The third section in this monograph deals with S & T in the pre-modern and British period in India. Smriti Kumar Sarkar examines an aspect of artisanal technology in India specially iron manufacturing and smithy by the tribal artisans. He established that the craft technology did not remain stagnant specially after 16th century AD, and specific methodologies are necessary to monitor the said change or technological evolution in artisanal technology. Sarkar's findings corroborate A. K. Biswas's earlier review of diversity in the iron and steel technology in pre-modern India (Indian Journal of History of Science, 29 (4), 1994, pp. 579–610). Amitabha Ghosh dwells on colonial constraints and technology, marginalised Indian attainments and the theme that in the contact between India and the West, the conquerors were the chief beneficiaries.

The third section of this monograph continues with several articles related to the British period in India. Chittabrata Palit dwells on science and nationalism in Bengal (1876–1912) and Chandana Roy Chowdhury highlights some pioneers of modern India.

As we enter the post-independence era and particularly the end of the twentieth century, it is instructive to note some salient features in modern science (fourth section in this monograph). C. K. Majumdar reviews the salient features of modern physics and their relevance to society and R. L. Brahmachary notes some developments on biology in the 20th century. Anirban Das presents an essay in the history of medical knowledge, the theme specifically dealing with the emergence of the concept of the 'body' as the three-dimensional space that purportedly holds the disparate (bodily) systems together. Somnath Ghosh emphasizes on relevance of chemistry to society and then proceeds to review the modern approach of 'new' chemicals : property-specific, theoretically predicted and eco-friendly green chemicals.

In the above backdrop, the fifth section focuses on history of science, technology and planning in contemporary India. M. M. Chakrabarty dwells on science and technology in India and the recent performances of the Indian universities, laboratories and industries. Biswadeb Chatterjee, an economist, critically examines the industrial scenario in West Bengal and specifies the remedial measures to overcome the ills. K. K. Dasgupta is more specific; he speaks from his personal experience, and his observations on the chemical industries in West Bengal are quite interesting. Sunil Sen Sarma's theme is the management of the riverine system in Eastern India.

Sankar Chakrabarty stresses upon the need for improvement of popular and mass-based science movements in India. Sushil Kumar Mukherjee has outlined the S & T policies in India. The government involvement in the promotion of S & T in our country has been based on S & T policy studies in other countries. Mukherjee has reviewed this involvement of the government since independence, the Scientific Policy Resolution of 1958, S & T Plan of 1974-1979, Technology Policy Statement of 1983, a new Technology Policy Statement of 1993, and of the seven categories of Technology

Mission programmes launched between 1985 and 1989. Mukherjee has emphasized in conclusion that the sectoral policies related to science, technology, energy, education, manpower, economy etc. are so inter-dependent that without integration of these policies, balanced national development may be difficult to achieve. Ashoke Mukhopadhyay also enters into a critical assessment of the S & T policy of India and its implementation and reaches very similar conclusions. S & T policy has many dimensions and social connotations. For example, it is imperative to create a true spirit of science culture amongst the research personnel and the masses. Policies should be evolved democratically. Mukhopadhyay argues that 'any fragmentary approach and attempt will not help to redress the situation.'

Mukhopadhyay comes very close to the concept of syncretism which has been outlined in the very first article of this monograph by Arun Kumar Biswas. Science and technology must be linked with other aspects of civilization and cultural development. In the last article of this monograph, Biswas presumes that all facts, scientific or historical, are rooted in the principle of causality and proceeds to investigate the social factors, the necessary and sufficient conditions for the optimum growth of S & T. According to him, the studies on history of science should never ignore the principle of causality and the efforts for integrating history of the past with the planning for future should never be abandoned. The sociological analysis has been extended to understand and diagnose the ills of the contemporary Indian science.

We hope that this set of articles may be found useful by the students and scholars as a basis for further studies in the area of history, science and society in the Indian context and that the model of juxtaposing history of science with futuristic studies may be considered to be a worthwhile pedagogic endeavour.

ARUN KUMAR BISWAS

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SECTION - I

HISTORY AND SCIENCE

I - 1

HISTORY, SCIENCE AND SOCIETY

ARUN KUMAR BISWAS

Abstract

This article seeks to capture the spirit of the monograph *History, Science and Society in the Indian Context* which could have been alternatively entitled as 'History and Planning of Science in the Indian Context'. As in the monograph, so also in this article, we endeavour to explore the majestic heights of two subjects : history and science, and their many similarities, which automatically lead us to examine the many contours and facets of history of science.

We would provide pointed references to some of the critical paradigms related to the history of science in ancient, medieval and modern India. The not-so-well-organised history of science movement and historiography in India would be reviewed.

The concept that the knowledge of history of science may be fruitfully utilised in planning of the future of science and society would be articulated and defended. This exercise however demands a very clear understanding of the desirable goal or goals for the entire human civilization.

Introduction

In his masterpiece, *Ends and Means,* Aldous Huxley proposed that there is a general consensus regarding the ends of the human civilization—peace, harmony and prosperity in the entire globe—but opinions vary as to the means by which we should be able to reach the ends.[1] Should our approach be political, cultural, economic, educational or spiritual ? Our considered opinion on this issue is that we do *not* have consensus regarding even the ends or goals of the human civilization. If we could sufficiently focus on, or articulate our goals, then probably the apparent divergence of the various means would appear to be redundant.

The very fact that we view the specific 'means' to be contraposed to each other proves that in our intellectual pursuit we have hopelessly dichotomised or compartmentalised our thoughts into political, spiritual etc. It is as if our hands and feet, kidneys and lungs, heart, liver and brain have unrelated functions and therefore do not have a common goal ! The goal is synthetic, and therefore the means or approach must necessarily be syncretistic. In other words, syncretism must be our ends as well as means, path as well as the destination.

Thus, to reduce, if not eliminate, gaps of communication and ideas, and to build syncretism of means should be one of our legitimate goals. We wish to illustrate the stated proposition in this article of limited scope in terms of three concepts : history, science and society.

The advent of modern science has been a big event in human history. Even during the ancient and medieval periods there was the subterranean flow of scientific thoughts and achievements. Yet, this influence has not been adequately reckoned in historiography. Arnold Toynbee's voluminous writing on history hardly mentions Newton's monumental work and its impact on human society. Conventional historiography has dealt more with the rise and fall of empires, dynasties, nations, and political groups rather than the social and economic aspirations of common men. The link between science and society has also been tenuous.

The subjects such as history of science and sociology of science are topics of very recent vintage. The gaps between history, science and society need to be bridged.

Reflections on History as a Subject

E.H. Carr's *What is History ?* and G.R. Elton's *The Practice of History* are still the outstanding explanations of what the historians actually do. [2,3] Carr introduced the idea that history books, like the people who write them, are products of their times. Therefore, history must be continuously re-written in the light of newly discovered facts and facts which were known even earlier, but not adequately valued by the previous scholars. The moot issue is to ascertain appropriate hierarchy of facts and causes. Whereas Carr championed a sociological approach to the past, Elton declared that any serious historical work should have a backbone narrative of political events. The post-modernist theory of 1980's has questioned the notion of scientific history and the premise of Carr and Elton that history is a search for the objective truth about the past. Against this disintegrative attack, Richard J. Evans has written *In Defence of History*, and ably defended the historian's capacity to reach genuine insights about past events.[4] The search for objective truth is of course an on-going and never-ending process.

E.H. Carr pointed out some resemblance between the subjects of history and science. Criticisms against his notion are entirely misplaced, since he never denied the obvious differences between the two subjects. His arguments can certainly be reinforced. If it is argued that history does not encompass the rigour of experiments as in natural science, we would be quick to point out that we do not experiment in astronomy or meteorology! We merely observe in these two areas, accumulate data and try to derive general laws therefrom. Therefore, there is nothing wrong in labelling history as a science for examination and interpretation of the past. Social science is a legitimate *wissenschaft*, to use the appropriate German word, which includes natural science or *naturwissenschaft*.

It is true that social events are not as predictable or reproducible as the phenomena in test-tubes or machines. But that is readily explained in terms of intervention of the much more complex factors of life and consciousness which are not operative in the inanimate world. Alexis Carrel emphasized on the hierarchy of scientific subjects : mathematics down to psychology. Mathematics is much more exact and psychology is 'probably in that stage of development as surgery when barbers were surgeons'. But then, psychology is much more complex since it involves 'life' and 'mind'. Mathematics is exact only because it is unencumbered by consciousness and entirely based on definition!

Through Figure 1 we postulate that there is a parallel hierarchy regarding reproducibility, verifiability and predictability in different sciences. With more and more intervention of consciousness, the knowledge system becomes less and less predictable. Newton could have thrown the apple downwards with greater force, he could have even thrown it upwards in the sky. When the gravitational force becomes compounded with the 'force' of free-will, mathematical quantification and predictability go topsy-turvy! Should we for that reason banish psychology, mystical experiences, history etc. from the domain of science ?

The Issue of Causality, Chance and Free-will

E. H. Carr asserted that 'the study of history is a study of causes', and that a historian's duty was to look for a variety of causes underlying any given event, find their mutual relationships, if any, and arrange them in some kind of hierarchy of importance. Following this dictum, Richard J. Evans achieved remarkable success in his research on Hamburg cholera epidemic of 1892. Scanning the immense amount of source material, he divided the causes into twelve groups and presented twelve parallel causal narratives for the entire period 1830-1892. Summing up, Evans argued that the epidemic occurred because the causative agents, the cholera bacillus, brought in by Russian emigrants on their way to America, passed through safety-nets all or some of which were present in other cities, but none of them in Hamburg.[5]

VERIFIABILITY

MATHEMATICS

PHYSICS

CHEMISTRY

BIOLOGY

PSYCHOLOGY

MYSTIC EXPERIENCES

INDIVIDUAL MIND

COSMIC MIND

("MAN THE UNKNOWN"
—ALEXIS CARREL)

REPRODUCIBILITY

Figure 1

THE QUESTION OF 'PROOF' : HIERARCHY OF KNOWLEDGE

We could easily show that many causes were inter-related amongst themselves rather than being independent or 'parallel'. Causal linkages could be analogous to an electrical circuit : sequential or in series, parallel or cyclic (Figure 2). Many factors are known to be mutually dependent. We have investigated the social factors in the promotion of S & T on a global basis, and with particular reference to India, on the premise that all facts, scientific or historical are rooted in the principle of causality.[6] This would be presented in the last article of this monograph.

We reckon that the principle of causality has not been universally accepted. Sir Isaiah Berlin, for example, was no admirer of historical determinism or the philosophy of impersonal 'cause'. He believed that history was governed more by chance, accident and indeterminacy, and lastly by unfettered free will of autonomous individuals. We may easily counter Berlin's antipathy against causality by pointing out that 'chance' or 'accident' is also a factor, and the only issue is its relative position in the hierarchy of a large ensemble of factors causing an event.

Following the jargon of mathematics, we may label some factors as 'necessary'; the event cannot take place if the necessary conditions are not fulfilled. The necessary factors alone however do not ensure that the event would indeed occur, for which 'sufficient' factors or conditions must be fulfilled. We propose that the gap between the 'necessary' and 'sufficient' is very often bridged by human individuals. Thus, free will is also a *factor*, the most important one, underlying scientific discoveries and history-making. Whether the apple fell down naturally on account of gravity, or was thrown down with greater force or thrown up in the sky depended very much upon Newton. The discovery of the law was also due to him. The role of consciousness is thus supreme. But when we reckon consciousness as one of the factors, must we subscribe to the lawlessness of 'indeterminacy'? Berlin suggested that being 'autonomous individuals' we may exercise 'unfettered free-will'. This may be true in principle, but what do we do in practice ? Do we not let ourselves be governed by social laws voluntarily ? Like a spider, Man weaves the web

CAUSALITY IN HISTORY OF SCIENCE

** HISTORY OF TECHNOLOGY IN ANCIENT INDIA

—(INSA) VOL. I, 1997, pp. 677-703

** SOCIAL FACTORS IN THE PROMOTION OF S & T

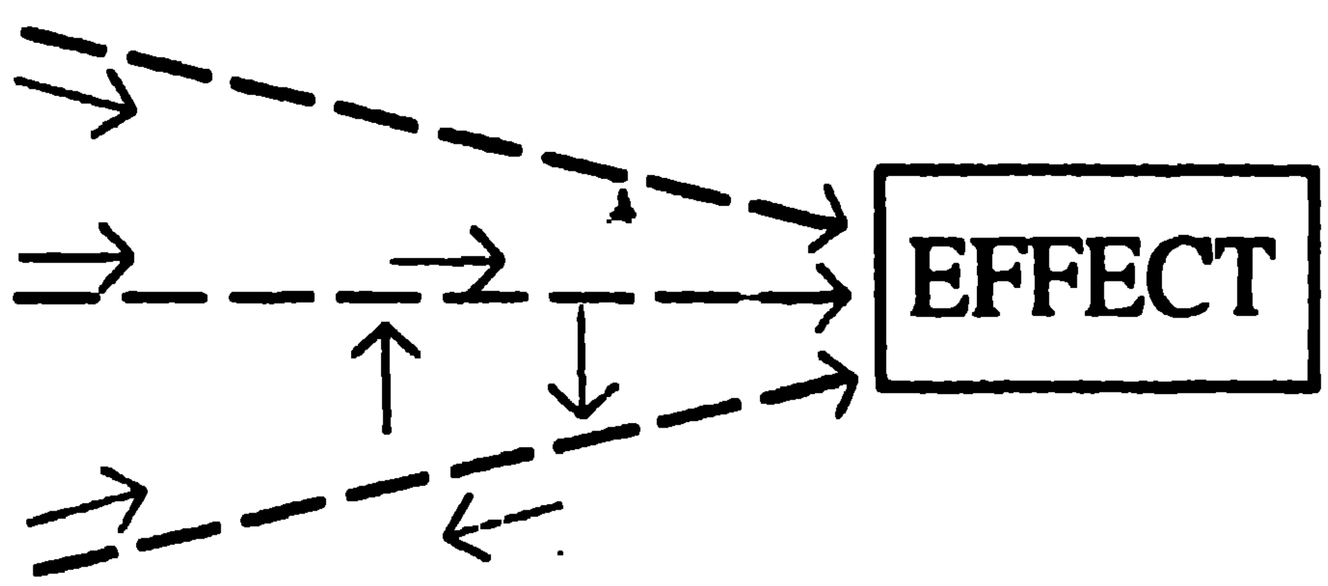
—JOURNAL OF THE ASIATIC SOCIETY 1998

'HISTORY' IS A *SCIENCE* OF DATA ON EVENTS ROOTED IN *CAUSALITY*

ITS *JUSTIFICATION* IN *FUTURISTIC STUDIES*

CAUSALITY NETWORK

CAUSES



FACTORS : NECESSARY & SUFFICIENT (?)

INDIVIDUAL : THE ELUSIVE GAP

MAN THE UNKNOWN

SO, LET US OPTIMISE THE NECESSARY FACTORS

ILLUSTRATION THROUGH CASE STUDIES

Figure 2

CAUSAL LINKAGES IN HISTORY OF CIVILIZATION

of history only to be entangled in it. The principle of causality or *Karma* is hardly violated.

In disagreement with Isaiah Berlin's point of view and endorsing E.H. Carr's, the modern historians are firmly pursuing the scientific approach, namely the theme of causality and quantification and mathematical correlation between causes and the effect. Convinced that not only demographic and economic history, but also social and political history, indeed all forms of history, should be subjected to this new scientific rigour, the cliometricians of the 1970's undertook an ambitious programme. Of course, success was achieved only on a limited number of statistical correlations and not on the really big issues in history[7]. But then history need not be apologetic, when meteorology, aided by high-speed computers, has not fared any better, and we are hardly able to predict the precise date when the next monsoon is going to reach India ! Covering six thousand years of human history and twenty-one human civilizations, Arnold Toynbee deduced, in his thirteen volumes of *A Study of History*, a series of general laws according to which civilizations rose, developed and collapsed. His 'laws' have not been widely accepted, but nevertheless his efforts are heroic, like many abortive efforts of Newton and Einstein. There is no harm if history, science and history of science pursue the theme of causality. Let the dissenters discover an alternative path.

The Sister Disciplines : HOS, POS and SOS

History and philosophy are the two generic terms which can be affixed to almost any term indicating a branch of knowledge. There have been studies of the history of fear, of smell, of madness, of childhood.[4] Similarly, we have philosophy of love, of music, of technology, of corruption and what not. It is very strange however, that very often philosophers are ahistorical in their approach and the historians are hostile to philosophy of history. Some historians argue that if they down their tools to listen to the philosophers, this may mean that the tools will stay permanently downed! [4] We reckon two sister subjects allied to history of science (HOS) namely philosophy of science (POS)

and sociology of science (SOS), and wonder whether the three sisters are staying together or drifting apart from each other.

During the eighteenth and nineteenth centuries, the history of science and philosophy of science were complementary subjects. In the early decades of the twentieth century however, the history and the philosophy of science began to be pursued relatively independently. With the rise of the Vienna circle and logical positivism in the 1920's, the philosophy of science rapidly became ahistorical in character. Karl Popper has made little appeal to the evidence of history to justify his position. Imre Lakatos proposed an analysis of the inter-relationship between the history and the philosophy of science. However, his bias is evident when he insists that the historian must necessarily rely on a philosophical view of science for his narrative and explanatory concepts. Paul Wood argues[8] that this thesis rests on two questionable assumptions :

"First it is assumed that the type of theory required by the historian to record and interpret the sciences of the past will be that offered by philosophers of science. This assumption is gratuitous since historians might equally well turn to sociology or social anthropology for their analytical frameworks as indeed they have recently begun to do." The other assumption that historical explanations are fully deductive in structure is also questionable.

"A consensus concerning the inter-relationships of the two uneasy partners has yet to emerge. Indeed, in practice, most philosophers of science continue to ignore history, while historians of science on the whole react negatively to the occasional historical forays by philosophers."[8]

The situation is dark indeed and must be rectified. In the ancient world, religion, philosophy and science were intertwined. Since Galileo, science and philosophy drifted away from religion.

In the twentieth century, science has become a slave of technology and free market, so much so that scientists are more concerned with 'puzzle-solving' (according to T. S. Kuhn) rather

than involvement with any philosophical question. Albert Einstein was most unhappy with the unoriginal, unphilosophical trends of modern science. Quite naturally, philosophers of science are getting alienated from both general philosophy and science. The practising scientists are rarely attracted towards philosophy of science, though this fact is not derogatory to either philosophy or science.

History as a subject is closer to sociology than to philosophy. The sociologists would like the historians to get out of the rut of the dynastic and chronological framework and delve more into the social milieu. But this is easier said than done particularly when we are examining the ancient and medieval periods for which the sociological data are not always so abundant.

Joseph Ben-David while examining *The Scientist's Role in Society* discussed different approaches to the study of the sociology of science.[9] He attributed the lack of continuous scientific growth before the seventeenth century to the inadequate institutionalisation of science in the ancient and the medieval world. Even in the modern world, a particular nation may fail to achieve scientific progress on account of a lack of political will for social experimentation, pluralism and programme for institutional changes. In such societies, 'waves of scientific enthusiasm are followed by vogues of antiscientism, romantic irrationality and even antinomianism threatening the very existence of science'. This is a topic of crucial importance to the historians of science.[9] Why modern science could not emerge in the ancient Greece, China, India or in the medieval Islamic world, why science is eluding the modern rich Arab world are important questions which can be answered more by the sociological analysis rather than philosophical.

Philosophers of science have immensely contributed to the subjects of logic, epistemology, discovery and pursuit of truth etc., but if they wish to influence history of science, they must not remain ahistorical. Paul Wood has aptly deprecated the insular attitudes of scholars and endorsed a more universal, interdisciplinary and all-encompassing approach :

"Historians of science have generally resisted the often patronising arguments of philosophers of science concerning the inter-relatedness of their subjects, much as their colleagues in general history have resisted the arguments of social scientists urging greater integration of the two disciplines. But as the social sciences provide the general historian with valuable theoretical resources, so the philosophy of science can provide the historian of science with analytical tools that can be refined through historical practice."[8]

Paradigms on Indian History and Science

Having made some general remarks on the history of science, philosophy of science and sociology of science, we may now turn to a theme which is one of our primary concerns namely, science in India and its historiography.

General history of India is a subject which is not only of stupendous proportion but also riddled with many controversies. Many scholars, both Western as well as Indian, have felt discouraged with the utmost uncertainty regarding the dates of the literatures such as the Vedas, the epics etc. To some extent the problem has been mitigated by steadily increasing number of archaeological evidences with the corresponding C-14 datings.

Correlation of the archaeological evidences with the literary ones is not always positive, but then efforts for correlation should be vigorously pursued. After all, the Homeric Troy was discovered archaeologically, so have been the Rigvedic civilizational sites (such as at Kalibangan) on the Saraswati river and the submerged Dwarka mentioned in the Puranas discovered through recent marine archaeology.

Even when the correlation is negative, some vital conclusions may be inferred. For example, it is now well-established that the epic *Mahabharata* was compiled in stages, and the archaeological features embedded in its literary descriptions correspond to a span of 1500 years i.e. from 1200 BC to 300 AD.

The scholars should not complain about 'paucity' of data in Indian history. Many archaeological samples are there yet to be analysed in sophisticated instruments; many literatures are yet to be read, translated and interpreted. The scholars' concern should rather relate to obsessive paradigms and set notions.

One such set notion that has been dogmatically held by senior scholars, and now being gradually dismantled, is the hypothesis or wild conjecture that the so-called Aryans came to India from Central Asia.[10] The racial paradigm has caused irreparable damage to the Indian psyche of unity and continuity of culture in the sub-continent. Therefore, the hypothesis can never remain unchallenged particularly when there is not an iota of archaeological proof to substantiate this wild hypothesis.

We have pointed out in one of our articles[11] that Chattopadhyaya, in his commendable attempt to glorify the Harappan civilization, and not so commendable effort to establish a rigid Marxist paradigm, has unnecessarily sought[10] to underrate the scientific contributions of the Rigvedic civilisation. We all share Joseph Needham's admiration (in the Foreword) for Chattopadhyaya's work[10] showing how much theoretical materialism there had been in ancient India, and how it had been systematically obscured and vilified by the theologians. But then, Needham also cautioned in the same breath that ' we must beware of pouring out the baby with the bath-water'. After all, the Rigvedic religion preached wonderful ethics which is 'needed today more than ever'.

In this connection we counselled that our paradigm for understanding Indian science should be less dogmatic and more open-structured.[11] We could not agree with Chattopadhyaya's dogmatic assertion[10] that those who object to the theory of Aryan invasion are 'frankly chauvinistic', since we believe that there is not a shred of archaeological evidence to justify the Aryan myth.[12]

The Cultures from 6000 BC Mehargarh to the Mature Harappan phase and then to post-Harappan phase Bhagwanpura, which shows Harappan and PGW pottery in the same level,

clearly depict a picture of continutity. We feel confident that further discoveries would provide us clearer picture about ancient Indian science during pre-historic and proto-historic eras.

During the historical period, the Hindu science witnessed spectacular rise and fall. What were the reasons? The scientific renaissance took place in Europe, why not in the Islamic countries or in China or India ? What was the nature of Muslim rule in India ? Islamic science had a glorious run in Spain of Europe, then why not in Sind or the rest of India? Why was Raja Rammohan Roy, proficient in Arabic & Persian, so bitter about the earlier Muslim rule in India, and was more hopeful about the British rule and the Western education ushering in modern science? Has colonial science in India been totally despotic?

Why has independent India failed so far to develop science and technology of the desired standard, to emulate the Japanese example?

Another issue that has been of great importance to all of us relates to the nature of Indian civilization. Has it been basically spiritual or material or logical/scientific in character? Does it reflect class struggle across the ages? Does the Indian scenario reflect certain cultural specialities not be found in other cultures?

We have raised the above questions not to answer them in our essay, but merely to suggest some of the basic concerns which should engage the attention of scholars. Of particular interest are the issues related to science in India. Historians of science in India should pursue the above problematic questions in great depth.

Historiography of Science in India

The origin of investigations in History of Sciences in India may be traced back to the 18th century, when the *Asiatic Society* was established in Calcutta in 1784 with Sir William Jones, the famous orientalist and linguist, as its first President.

Jones had described the excitement he was having (as regards the prospect of scientific research in India) while he was

approaching India over the Arabian sea. According to him, the vast Asian amphitheatre has ever been esteemed the nurse of sciences, the inventress of delightful and useful arts. How true he was! Raja Rammohan Roy was a ten-year old boy when the Society was founded. Later he was steeped in the knowledge of ancient literature in Arabic, Persian and Sanskrit and yet he unhesitatingly advocated in 1823 a more liberal and enlightened system of instruction, embracing mathematics, natural philosophy, chemistry, anatomy with other useful sciences. Half a century later, the pioneer of scientific education in Japan, Fukuzawa was arguing in the same vein in favour of utilitarian teaching in science.

The Asiatic Society began its first serial publication the *Asiatick Researches* in 1788, which ran into 20 volumes and later replaced by the *Journal of the Asiatic Society of Bengal.* The early historical researches on the Indian sciences, published in the said journals, were carried out by European scientists and orientalists. The Europeans like Joseph Tieffenthaler, W. H. Hunter, H.T. Colebrooke, G. Thibaut, Jean Filliozat, A.B. Keith, M. Winternitz set high standard of research which inspired many Indian scholars of classical languages to take interest in studies of Indian scientific source-material. Bapudeva Sastri, Sudhakara Dwivedi, and later Brajendra Nath Seal, P. C. Ray, G. N. Mukhopadhyaya, B. K. Sarkar, P. Neogi, H. D. Sankalia, B.B. Datta etc. made many important contributions to the history of sciences in India.

Special mention must be made of two practising geologists, one European and the other Indian, who took special interest in history of science. V. Ball meticulously recorded in his *Economic Geology of India,* the achievements of ancient India in the fields of geology, mineral exploitation and metallurgy. Apart from writing a centennial review on the achievements of the *Asiatic Society* (1784-1884), Pramathanath Bose was the first Indian to attempt a comprehensive review of Indian history with special emphasis on science and technology during the ancient, Muslim and the British period.[13] Prafulla Chandra Ray had written his

classic work on Hindu chemistry[14] in 1902 which was updated in an edited version five decades later.[15]

We must not lose sight of the fact that the second half of the nineteenth century witnessed the birth of indigenous science movement led by Dr. Mahendralal Sircar. Assisted by Reverend Father Eugene Lafont, Sircar founded in 1876 *The Indian Association for Cultivation of Science*. This Association triggered the first-ever modern scientific research in India to be done by the Indians themselves. It produced the first Indian Nobel-laureate in science : Sir C. V. Raman and was associated with many stalwarts like Sir J. C. Bose, Sir Asutosh Mookerjee, Dr. Meghnad Saha etc. who heralded modern science in the Indian scenario.

In Mahendralal Sircar's vision it was not simply the initiation of an indigenous science movement which was called for but also the necessity of a history of science movement in India. He published in the *Hindu Patriot* (January 3, 1870 issue) the Prospectus of the proposed Association which included the following proposal :

"A correlative object will be to rescue from oblivion whatever is connected with India, ancient or modern. Thus the Association will aim at editing and publishing the ancient records, so replete with interest and wisdom."

During nearly 125 years of its existence, the Association has gloriously pursued its principal objective of cultivating science so much so, that it could not adequately render justice to its 'correlative object' of pursuing the subject of history of science. Nevertheless, practising scientists such as P. N. Bose, P. C. Ray, P. Neogi etc. undertook commendable assignments in historiography of science, evidently taking cue from Mahendralal Sircar's exhortation.

Brajendranath Seal and Swami Vivekananda were classmates, contemporaries of P. C. Ray, and they carried historiography of science in India to the philosophical and paradigmatic levels. B. N. Seal wanted to stress in his classic work[16] that :

"The Hindus no less than the Greeks have shared in the work of constructing scientific concepts and methods in the investigation of physical phenomena, as well as of building up a body of positive knowledge which has been applied to industrial technique."

Swami Vivekananda had unique insight regarding Indian civilization and stressed in his remarkably illuminating essay *Historical Evolution of India* that India always enjoyed a strong material (apart from spiritual) civilization fostered by science and technology. This healthy paradigm contradicts the Gandhian view that the Indian ethos has been wholly spiritual deliberately ignoring material advancements. In his celebrated book *Discovery of India*, Jawaharlal Nehru followed Vivekananda's model rather than Gandhiji's. His disagreement with the Gandhian view on modern science and technology as articulated in *Hind Swaraj* is quite well-known.

Post-Independence Scenario

As the first Prime Minister of independent India, Jawaharlal Nehru patronised the growth of not only science in India, but also (as a committed historian) its historiography.

A symposium on History of Sciences (hereafter abbreviated as HOS) in South Asia, organised in collaboration with UNESCO in November 1950 at the University of Delhi, first emphasized the importance for a co-ordinated and sustained effort in the study of HOS. [17]

The Indian National Science Academy (INSA) initiated in 1955 a plan on HOS in collaboration with the Asiatic Society. In 1965, INSA set up *The Indian National Commission for History of Science.* The Commission has been publishing a well-established quarterly journal : *Indian Journal of the History of Science* (IJHS) and operates through its three advisory committees, one each for *ancient, medieval* and *modern* period. On the advice of these three committees, the Commission supports on an average thirty projects annually. During 1992-93, for example, 28 research projects (12 ancient, 9 medieval, 7 modern)

were sponsored and these were spread over various disciplines, like exact sciences, architecture, technology, Indian medicine etc.[17]

The present author published in 1969 a small but probably the first comprehensive monograph on science in India.[18] Two years later, INSA released a more comprehensive history of science in ancient India (upto 1200 AD).[19] Recently three monographs on history of technology in India—for the ancient, medieval and the modern period — have been planned by INSA.

The Indian Council of Philosophical Research has sponsored a Project on History of Indian Science, Philosophy and Culture under which publication of several multi-authored volumes is contemplated.

The Centre for History and Philosophy of Science, Bangalore, has been working on several projects such as Source Book on Indian Chemical Practices, Source Book on Indigenous Tradition in Indian Navigation etc. The founder-director of the centre Dr. B. V. Subbarayappa has published *A History of the Indian Institute of Science, Bangalore*, established by J. N. Tata in 1909.

Next to INSA, the National Institute of Science, Technology and Development Studies (NISTADS), New Delhi has made significant contributions in the area of history of science in India. Founded in 1981, the NISTADS has been engaged in multi-disciplinary activities in several areas such as :

Science and Technology in Ancient India, modern science in the 19th Century India, the nature of the colonial period science in India, foundation and methodology of theoretical sciences, the structure and dynamics of scientific theories etc.

The Jamia Hamdard University, New Delhi has the Department of History of Science and Medicine, which has been working on history of exact sciences and history of Unani (Graeco-Arab) medicine in medieval India, unearthing many primary sources in Arabic and Persian manuscripts. Since 1993, the university has been publishing a journal : *Studies in History of Medicine and*

*Science.*Since 1979, The Indian Society for History of Mathematics, New Delhi has been regularly publishing a bulletin, *Ganita Bharati,* which has 'caught the attention of world historians of mathematics'.[17]

B. M. Birla Science Centre, Hyderabad has developed interest in history of astronomy. PPST Foundation, Madras has resolved to promote studies concerning 'the basis for a science and technology having its *roots* in the Indian scientific and technological *traditions* and oriented towards *meeting the needs* of the Indian people.'

Teaching in History of Science

One of the objectives of the Indian National Commission for History of Science was "to appoint whole-time Professors and Readers to conduct research as well as supervise the work of research scholars and technical assistants. By such means a *cadre* of science historians would be trained from which the universities might be able to recruit staff for their history of science departments." However, this objective has not yet been fully realised.[17]

The Commission as well as the UGC have tried to introduce the HOS culture in the Indian universities without much success. Some universities like Delhi, Aligarh, Jaipur, Calcutta, Pilani, IIT's at Kharagpur, Kanpur etc. have some modicum of HOS programme. A few universities such as at Ranchi, Bhagalpur, Meerut, Kurukshetra, Lucknow, BITS Pilani, Gurukul Kangi University at Hardwar, Mithila University at Darbhanga, Bihar University at Mazaffarpur etc. have approved doctoral theses on history of science.[17]

The Asiatic Society which had done considerable work on history of science and modern science in India, celebrated its bicentenary by establishing a Centre for History of Science in 1986. The Centre worked out a programme of research and teaching, leading to the M.Phil. degree, but this programme could not be implemented on account of various reasons. Instead, the Society introduced in 1994 a one-year certificate course in History

of Science which has been offered for several years during 1995-1998, and availed of by about a dozen of students. During April 1999, a variation has been experimented upon : a ten-days short intensive course on history and planning of science. This monograph is an outcome of that course.

A special mention may be made about the HOS-related activities at IIT Kanpur.[20] Since 1988 or thereabout Professors P. R. K. Rao and A. P. Shukla introduced a course *History of Ideas* which dealt with philosophy and history of science in Greek, Arabic and the Western world. Following their leadership, the present author of this article introduced another special course entitled *History of Science in India.* Both the courses succeeded in attracting and motivating a large number of students in the HOS area. The INSA report[17] mentions several institutions, groups and individuals working on different HOS topics in India. Whether their efforts would total up to a coherent and self-sustaining HOS movement remains problematical.

Necessity for a National Society

The crucial problem for the growth and sustenance of any new inter-disciplinary subject is the issue of a well-defined cadre of scholars. During the 19th and 20th centuries, the HOS movement in India has been sustained by a handful of researchers. It is doubtful whether the number of scholars working in this area at the same time ever exceeded 20-30, and whether they could devote full time in their research in HOS.

The scholars have always had to attend to their parent disciplines such as Indology, literature, chemistry, philosophy, general history, astronomy etc. and therefore, the growth of the subject HOS has been tardy. Now the subject has reached such proportions in complexity and magnitude all over the world, that a thoroughly professional approach has become essential. This means specific curriculum, teaching staff, students and research scholars, library facilities, budget etc. are required, and there is the paramount importance of raising a separate cadre to nurture this subject.

But the question is who is to bell the cat ? Which university or universities? The UGC, the INSA or any other organisation? Any historical or scientific institution?

We are not futurologists, and therefore cannot answer the above questions. However, we propose that fertile ground be prepared with the hope that some suitable seed may be available in the near future. In other words, in the HOS area we may start with a 'think-tank' : A NATIONAL SOCIETY.

The present author is probably the first in proposing that the scholars, scattered as they are in different disciplines and institutions, may now unite to constitute an Indian Society for History of Science (ISHS). The Society would host periodical meetings for the scholars to deliberate on their work, plan collaborative ventures, discuss common problems of academic and administrative nature and their solutions. Such a Society would not only unite the scholars but also link the various academic bodies and institutions which have, or aspire to have, programmes related to HOS. The Society would invite sister societies such as those of historians, archaeologists, scientists etc., to send their representatives for participation and deliberation in the decision-making committees of ISHS. It is earnestly hoped that ISHS would help the Nation in evolving a viable and permanent cadre for HOS and in providing the academic and administrative infra-structures for its professional sustenance.

The proposed ISHS should have distinct divisions in not only history of science, but also philosophy of science, sociology of science, popularisation of science and scientific culture, education, research, planning and development related to science and technology etc.

Lastly, the Society and the Movement should be actively concerned with a much broader framework, namely history and *planning* of human civilisation in its entirety.[20]

Planning for Science and Society

The readers of this article would notice that we are proposing to give a strong futuristic bias to our history of science movement.

We are interested in not only *history* of science but also *planning* for future of science and society with the premise that historical experience can be utilised to predict or control the future.

Historians are conventionally the scholars of the past and not the future; they assert that they are not futurologists. Yet as intelligent human beings they should be interested in the future like anybody else, and need not mind if the data of the recent past are extrapolated for the forecast of the immediate future. This is what all social planners do. The planners recommend concrete steps so that specific and desirable results may be obtained. Scientific experimenters extrapolate existing data in the light of an adopted model or paradigm to predict forthcoming results. If there is a mismatch between the predicted and the actual results, the paradigm stands falsified and is subjected to revision. The same methodology may be adopted for history and planning of science.

Robert Fogel, the American apostle of quantitative and econometric history, believed that *scientific* history can be modelled mathematically, and the general hypothesis can be statistically tested. The premise is that there are systematic relationships between events, structures and processes in history.[21] History cannot create laws with predictive power, but it can identify, or posit with a high degree of *plausibility*, patterns, trends and structures in the human past and in that light, provide us with some inspiration or a warning for the future.[22] What the science of meteorology in the modern stage of development promises to us is not far superior.

Syncretism : Our Goal

In the introduction, we referred to Aldous Huxley's famous statement that 'there is a general agreement with regard to the human goal, but not so with regard to the roads which lead to that goal', and expressed our reservation whether there is any agreement even regarding the goal. Those who believe that the royal road to a better world is the road of economic reform evidently view the human goal more in economic terms rather

than spiritual. Similarly, those who recommend that the spiritual path is the best, are also exclusivists, and their vision of human goal is more spiritual than economic or material. Thus, a disagreement on the method implies some disagreement on the goal as well. Only a syncretism of methods can correspond to some unanimity of goal, involving liberty, peace, justice and brotherly love.

In this article of limited scope, our focus is on science and its impact on society. The very first thing we should notice is that science is merely one amongst the many useful components of human culture. Its impact on society can be disastrous, as in Hiroshima, Nagasaki, Vietnam, Bhopal in our country etc., if it is compounded with imperialism and consumerism instead of environmental ethics, compassion and spirituality. The goal of science is indissolubly linked with the other laudable aspects of human culture.

Elsewhere, I have delineated[23] how the ideas of Swami Vivekananda (1863-1902), the great saint of India, can be adequately described in terms of four words beginning with S : science, spirituality, socialism and secularism. We find another rare individual Joseph Needham (1900-1995) who wanted to establish human thoughts and endeavour on the 'tripod' of science, spirituality and socialism.[24]

By secularism we mean not irreligious atheism but equal respect for all religions consonant with the spirit of democratic pluralism. The term 'religion' has unfortunately been contaminated with the idea of dogmatic theology and obscurantism, and hence we prefer the term 'spirituality' which denotes the mystic joy of the holy and the ascent to a code of ethics. Genuine socialism according to us corresponds to the Sanskritic concept *sāmya* which combines the economic doctrine of equality with the sense of spiritual brotherhood, compassion and democratic pluralism. Our syncretistic view is schematically shown in Figure 3.

Now we wish to indicate how the goals of science and society may be synchronised with the spirits of (a) religion in the sense

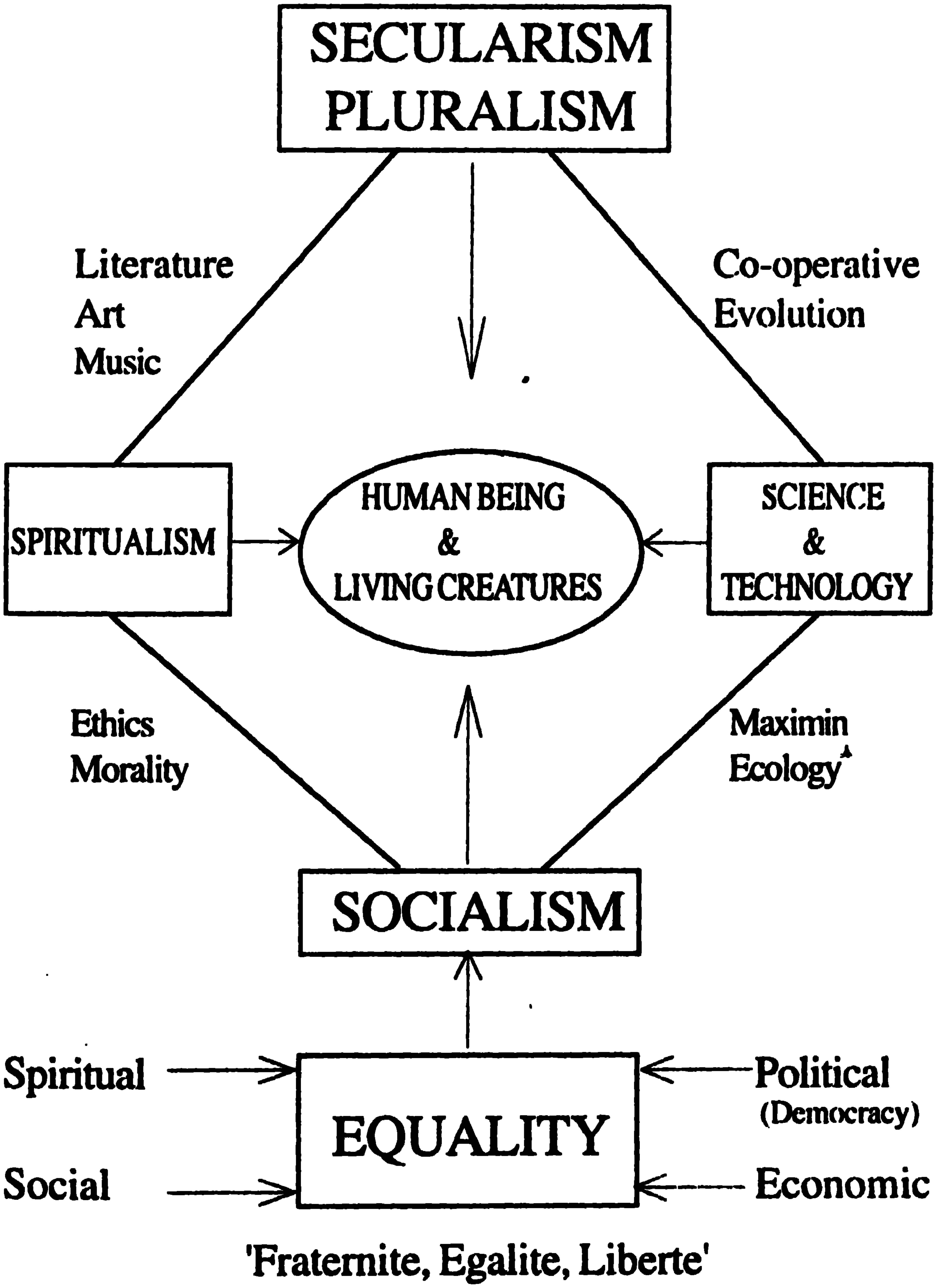


Figure 3

SYNCRETISM OF VALUES : MULTIPOD OF HUMAN CONSCIOUSNESS

of spirituality and (b) socialism in the sense of *sāmya*.

Herbert Spencer once remarked that of all antagonisms of belief, the most profound is between science and religion. Perhaps the episode of Galileo and the famous 'inquisition' was in his mind. But to-day there is not so much animosity, and the Vatican is about to apologise publicly regarding the injustice done to Galileo.

Those who claim that religion cannot be reconciled with the scientific spirit raise the issues of 'proof' and 'reproducibility'. In one of my writings[25] as well as in Figure 1 of this article, I have emphasized that the 'objective' truth of science and 'subjective' truth of the mind and mystical experiences are of different genres and hence call for different kinds of 'proof'. The only laboratory for the religious experiment is the advanced human mind: the 'proof' cannot be shown, it can only be experienced. Aldous Huxley who had earlier (1960) delivered at M.I.T., U.S.A, his Centenary Lecture series entitled *What a Piece of Work is Man* wrote to me in his letter of 19 February 1961 : "No subjective experience can be demonstrated. How do you demonstrate music?"[25] Music is not appreciated by the deaf, and God exists only for the mystic who has experienced Him.

One meeting point between science and religion is the research on consciousness in which the human mind is attempting honestly to understand itself. The physicists and biologists are negotiating a dialogue on consciousness with the proponents of religion.[26] Francis Crick,[27] Patricia S. Churchland[28] and others believe that neuroscience may solve the problem regarding the working of human mind. Other scholars such as David J. Chalmers insist[29] that knowledge of brain alone may not get the scientists to the bottom of the phenomenon. The International Conference on Human Consciousness was held in Arizona in April 1994 and its Proceedings were published two years later.[30] A postscript in this book proclaims : "Science and philosophy face a daunting chasm between reductive materialism and subjective experience

.... The brighter we illuminate reality with the light of science, the more we become aware of the surrounding darkness".

The heart of religion or spirituality is the perennial corpus of mystical experiences of the holy which need not be contested by modern science. After all, this sense of the holy provides not only a deep purpose of human existence but also an 'ascent to a code of ethics'. The senses of the unity of the entire living world and of universal brotherhood directly emanate from the claimed realisation of the Supreme Creator, and suggest a spiritual version of socialism as the goal of human civilization.

The Sanskritic word *sāmya* stands for the entire spectrum of related concepts : equality, sameness, evenness, impartiality, justice, equilibrium, togetherness, universality, social concord, equanimity, equability etc.[23] Even the shorter French list : egalite, liberte, fraternite indicates the majesty of socialism which has not been reached during either the French or Russian revolution, but is certainly attainable in the not-too-distant future. The schematic presentation in Figure 3 indicates the multi-dimensionality of egalitarianism : economic, political (democracy), social (caste and other privileges to be abolished), and spiritual brotherhood to be ensured. The human civilization must rest on a stable multipod, science being only one amongst the many legs of the multipod.

When we study history, science and society, the multi-dimensionality of human civilization must never be lost sight of. The greatest contribution of science is the scientific or logical attitude which has resisted religious obscurantism; this welcome attitude must ever be resolutely extended to the social plane. Science in our civilization may be compared to the brain in human body. Spirituality however provides the perennial vision and without this we are blind. Bereft of the legs of spiritual socialism we are lame and we cannot move forward towards our goal despite science and religion; as a matter of fact, we may move backwards, as we did in the past when many imperialist wars were conducted and exploitations perpetrated in the name of

religion and through the machination of science.

What we have outlined is the spirit of Needham's 'tripod'[24] and Swami Vivekananda's syncretism.[23] If we adopt syncretism as our path as well as goal, the question of divergence in the human ends and means[1] would not arise. History and planning of science should be studied rigorously, critically and quantitatively as a part of history and planning of human society and civilization. The approach must be holistic, eclectic and syncretistic.

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I - 2

HISTORICAL KNOWLEDGE AND KNOWLEDGE OF HISTORY

SANTANU CHACRAVERTI

[A presentation these days, that seeks to do justice to the above title must at the very least provide a review and critique of Collingwood's *The Idea of History*, E. H. Carr's *What is History* along with a critical introduction to Michel Foucault's notion of genealogy[1] as opposed to causal explanatory history. The present discussion fails on all the above counts and hence, quite frankly, fails to do justice to its title. Moreover the reader is likely to find it uncomfortably epistemological in its focus and concern.

What then is its justification? Its justfication, if any justfication is at all possible, rests solely on the fact that it seeks to introduce the uninitiated to some of the basic epistemological problems associated with the notion of history. Coming as it does as an introductory topic in a *history of science* programme it intends to shake any false certitudes that the participant may entertain regarding our knowledge of the past as well as our knowledge of past knowledge. The presentation is not at all comprehensive, it is frankly introductory. It will have achieved its purpose if it succeds in generating in the mind of the reader a certain degree of confusion. For confusion that comes through the destruction of complacency is the grandma of all intellectual yearnings.

The reader who has been through the entire length of this presentation is likely to find in the Notes & Reference Section works that will guide, enlighten and generate new levels of confusion. And that precisely is as it should be.]

The term 'history' might be used in two basic senses : (1) As the course and sequence of past events and (2) As a description of past events. There is always a need to distinguish between the two senses of *history*.

'History' as in 1 occures in such utterances like "the history of the solar system", "the early history of humankind", "the historical development of the game of football" or " a new history was made the day Mohan-bagan defeated Yorkshire in a football match". We use 'history' as in 2 when we say that "E. H. Carr wrote an authoritative history of the Bolshevik Revolution".

Now 'history' in the sense 1 may refer to any particular course of past events while 2 usually refers to accounts of past *human* events. Thus when we say that a particular college has *History* Department we are not implying that the college offers courses in the geological history of our planet or the evolutionary history of anthropoid apes but rather that the college provides its students with the opportunity of dwelling on accounts of our ancestral deeds and misdeeds.

To belabour the point further we might say that Aurangzeb made *history* (as in 1) but Jadunath Sarkar wrote a history (as in 2) of Aurangzeb and his times. If you think that I am harping too long on a rather obvious distinction please bear with me for a few more moments. To my mind this apparently trivial distinction conceals beneath itself the most difficult problem of the philosophy of history.

If I say that 2 depends on 1 you will immediately agree, for that is obvious. But if I say that, in a very important sense 1 also depends on 2, you will, unless you have already played around with epistemological problems, be perplexed. But since I have made it my business to perplex you I hereby declare that in a very profound sense 1 does depend on 2.

What I am saying, though shocking to the uninitiated is quite simple and direct. There are (a) things and events and (b) our decriptions of them. No one disagrees that the elements of **b** are shaped and conditioned by elements of **a**. But I am saying that it is equally true that elements of **a**, *as we know them*, are selected, toned and coloured by elements of **b**. If you are a good polemicist you will immediately see that thc catch is in the clause "as we know them". But I will not give you the opportunity of quibbling now and proceed with my arguments.

The philosopher Immanual Kant came up with an important distinction between the *thing-in-itself* and the *thing-as-it appears to us*[2]. This distinction of his rests on a simple argument. We do not and cannot know the *things* of the world as they *actually are*, but as they come to us filtered through our senses and cognitive apparatus. We are lifelong prisoners of our cognitive setups and so we cannot know the *things* in their pure non-apparent *forms*. Kant's distinction is perhaps valid, yet extremely problematic, But we shall come to these problems a little later. Now let us get back to history.

For any given individual it is a truism that s/he gets to directly perceive only a minute fraction of the events about which s/he knows. The bulk of what s/he knows is based on what traditonal Indian philosophers called *shabda*, or testimony. But testimony is *someone's* testimony, hearsay is someone's say so. It is knowledge no doubt, but knowledge at second, third or n^{th} hand, n often being an indefinitely large number (as in the case of rumour). Most of the information that gets relayed down to us gets filtered and toned through the senses and brains of 'observers' in series, and in most cases personal corroboration is impossible. So even if we rule out conscious deceit, it is quite understandable that the bulk of my information is by no means objective but coloured and shaped by the consciousness of others.

But what about the things and events which I perceive directly? Is not my own perception equally subjective and coloured? Kant would have nodded his head in agreement but I shall shelf both this and Kant and continue with *testimony*.

Any intelligent newspaper reader knows that the 'news' that s/he reads is selected, shaped and toned by editorial policy and by the correspondent's attitudes and bias. Which is why not every thing 'important' that happens gets carried or is given 'due' weight and one needs to survey any number of newspapers to get a 'balanced' view of things. An alert and intelligent person is always sceptical of his/her sources s/he learns to question the media and beware of quick conclusoins. S/he knows that one does not get to know the 'real' world but a world mediated, filtered and packaged through "news" items in papers, radio and television channels.

If this is true of the present it is of course truer of our knowledge of the past. We have no direct access to the world of the past. We are told that the present is shaped by the past but is it not equally true that we of the present shape our past according to our own likes and dislikes? In studying history what is the epistemological status of the past that we study?

Say you are interested in knowing all the 'facts' relevant to the decline of the Mughal empire where would you come across such 'facts' today? As a beginning you might try to read up all that has been written on the subject since Jadunath Sarkar. If you do manage to accomplish such a formidable task of digestion you will be rightfully treated as highly knowledgeable in the area but you will still not be taken as an expert. This is because you have still not visited the 'facts' themselves and have had a genuine taste of historical reality—i.e. you have not yet examined the documents of the period, gone through contemporary writings by Indians and foreigners and examined such solid three dimensional facts as would be considered valuable by archaeologists. You can of course improve your qualifications by doing all this and establishing your credentials by contributing to a number of learned journals. Now of course you will be considered a member of the 'experts' club. Can it be said now that you have a more or less correct and objective view of the period you have so laboriously studied? Hardly. Let me explain.

(1) When you have read the accounts of historians you have been confronting the past very indirectly, through the filtered gazes of idiosyncratic individuals, conditioned, limited and circumscribed by their attitudes, training personal inclinations and political and cultural contexts.

(2) When you waded through contemporary writings you were faced with the same problem. Their contemporaneity solves nothing, for the writers are persons caught in the web of history and imprisoned by their own subjectvities and perhaps worst, being contemporary they lack the distance and detachment necessary for evaluating the events they observe.

(3) As regards the epistemological status of documents as source material for unearthing historical reality I will bring in the verdict of E. H. Carr.

"... But what, when we get down to it, do these documents—the decrees, the treaties, the rent rolls the blue books, the official correspondence, the private letters and diaries—tell us? No document can tell us more than what the author of the document thought—what he thought had happened, what he thought ought to happen or would happen, or perhaps only what he wanted others to think he thought, or even what he himself thought he thought ....."[3]

So much for documents.

(4) As regards archaeological facts the situation does not appear to be much better. Recent debates in archaeological theory show that the bulk of current research is pestered by problems of perspective and interpretation and that archaeological 'facts' no longer enjoy the secure sanctity that they seem to have enjoyed in a positivistic age.

Such is the character of historical objectivity. An undergraduate student of history quickly learns that historians never seem to agree among themselves. S/he also learns world. And this is precisely why, while reading history, one should also try to read the historian.

It is in this sense that I asserted that not only are accounts and descriptions of the past determined by what happened in the past but that the latter is shaped by the former. For, to paraphrase Kant, we do not get to know the past-in-itself, but the past as it appears to us through the constructions of historians and archaeologists. The latter in their turn are dependent on literary and archaeological sources the epistemological status of which we have already examined.

Now let us get back to Immanuel Kant's *thing-in-itself*, that inscrutable entity that is the source of our impressions but which we never get to know as it actually is. Let us take our very familiar *moon* as an example of the *thing-in-itself*. What then is the *moon-in-itself*? We do not know and cannot say for we do not perceive it. It is the supposed source of our perceptions, not the perception itself. Yet does this entity, so irretrievably beyond our perceptions, hold any meaning for us? No and yes. It holds no experiential meaning for us, only perhaps a conceptual one. The moon-in-itself is the moon absolutely independent of us and our perceptions, the moon that we cannot experience and hence for us an experiential zero. But if we are realists, which *we all are in practice*, we know conceptually that there is a moon independent of anybody's perception, but which acts as a source of all our moon-perceptions. This immediately recalls to us the renowned Tagore-Einstein discussion but we cannot go into that here.[4]

What applies to the moon applies to the past. There is conceptually, a past in itself, the 'real and objective' past, the course of 'real' happenings and events. It is the historians' business to understand this past as it actually was, but as we have seen s/he never gets to do that but deals in shadows and produces accounts which are at best imaginative constructions.

If this be so then what can we say regarding the truth-value of historical accounts? Is it possible to say that *this* account of events is truer than *that*? If "real reality" is irretrievably beyond us then how can we compare the truth-value of one narrative with that of another? This is a thorny epistemological problem which is pertinent not only to history but to all knowledge and in order to

make even the briefest possible comment on it we will have to proceed to the next part of our discussion, *history and science.*

History and Science

With Thomas Kuhn[5] and his more militant ally Paul Feyerabend[6] the notion of scientific truth has taken a severe beating. But long before Kuhn, Henri Poincare and Pierre Duhem in France, W. K. Clifford[7] and Karl Pearson[8] in England, instrumentalist philosophers like William James and John Dewey[10] in U.S.A. and Ramendrasundar Trivedi in Bengal had produced brilliant critiques of the notion of scientific truth.[11] Not withstanding Karl Popper's spirited defence of the realist position we nowadays speak more in terms of paradigms than in terms of truth.

In the Kuhnian vision the 'progress' of science is not a sequence of steps proceeding towards greater and greater approximation of truth but a series of paradigm shifts, successive paradigms being simply different from their predecessors rather than being epistemologically superior. In fact paradigms resist being compared in terms of truth value for (1) the paradigms have different presuppositions and concerns : (2) the terms and concepts employed in different paradigms are often incommensurable and (3) comparison between paradigms cannot be achieved from a transcendentally impartial position but has to be done from within a certain paradigm.

The same approach may be profitably employed in a historiographical discussion. In comparing Herodotus to Braudel it must be borne in mind that these historians are operating under different paradigms and indeed they have quite different ideas about what constitutes history. That most of us would find Braudel's approach closer to what we could call our own, stems largely from the fact that we share Braudel's epoch and milieu and not those of Herodotus.

Many branches of the physical and the natural sciences have one advantage that history as a discipline lacks. The former are amenable to what an instrumentalist philosopher would call a

'pragmatic test'. For an instrumentalist philosopher it is meaningless to say that the Keplerian-Newtonian theory is truer than the Ptolemaic one, but it is meaningful and valid to say that the Keplerian-Newtonian theory has a far better predictive potential than the Ptolemaic one. This predictive aspect is one that history lacks for it is by definition concerned with the past rather than the future and is concerned with retrodiction rather than prediction. Since we cannot by the nature of the subject apply predictive tests to historical theories and accounts it becomes difficult to compare between rival accounts. (There are a group of scholars who think that mathematical models of the past may be profitably used in predicting trends and events of the future. If their efforts do gain a semblance of success then a new branch of history will emerge that might be compared with branches of physical science. But even then the problem of *truth* will remain, as the instrumentalist critique of truth will remain to be taken into account).

Notwithstanding all this, neither the natural or physical scientist nor the historian can entirely shake-off the notion of reality-in-itself i.e. what really happens and what really happened. It is in order to find out about real events and processes that we choose patterns of explanation and rules of recognising and evaluating 'evidence'. In modern medicine we do not accept witchcraft as a cause of disease, we prefer to settle on genes and microbes. Similarly in history we no longer accept divine, demonic or astrological explanations—we strive to make do with ideological motives, cultural orientations, economic drives and political ambitions instead. These are, within our current paradigm, acceptable explanations.

The difference that history has with most physical and natural sciences, e.g. chemistry, is that in the latter we have scope for conducting controlled experiments. But what is possible in the study of chemical processes is not possible in the case of historical processes. The causal historical agents that we may choose to identify in our explanatory efforts cannot be studied under laboratory conditions or subjected to experiemental control. We

have to test our hypotheses in the light of such 'facts' that we choose to call evidence and rest content. But then this applies to many other areas of knowledge that we accept as valid.

Uptil now I have been employing the terms 'paradigm' and 'milieu' in a way that might suggest that at a particular point of time a particular paradigm reigns supreme. But that is not true. Several paradigms may be and usually are in competition at a particular time. At the present moment we have liberal-rationalist, Marxian, Foucauldian, Cultural History[12] and various hybrid approaches contending in the academia of history. Entrance to the discipline is free, as it should be, to anthropologists, sociologists, archaeologists, political scientists and philosophers. Paradigms and approaches abound. The more the merrier. And on this note I shall close my presentation.

References and Notes

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3. E. H. Carr, *What is History*, Penguin Books, 1964, p.16.
4. See excellent Bengali translation of the debate by S. N.Bose in *Satyendranath Basu Rachana Sankalan'* Bangiya Bigyan Parishad, Calcutta, 1399 B.S., pp. 471-20.
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11. See *Bichitra Jagat*, in Ramendra-Rachanabali, Vol III, Bangiya Sahitya Parishat, Calcutta 1356 B.S. pp. 207-482.

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SECTION - II

SCIENCE IN THE ANCIENT WORLD

II - 1

THE HARAPPAN CHAPTER IN THE MAKING : THE STORY OF SCIENCE AND TECHNOLOGICAL EXPERIENCE IN EARLY SOUTH ASIA

NUPUR DASGUPTA

With the recent findings in the archaeological artifacts and their updated analyses, the protohistoric chapter of the Indian South Asia is increasingly assuming the status of a substantial academic area. The factors operating in the genesis of the first cultural development in South Asia are now discernible from these works. A study of these factors reveal succesive stages of human endeavor at bettering their lifestyles and coming to terms with their natural conditions, at the base of which lay the instinct of survival. The experimentations with nature and its resources, human and animal world, were all a part of a repetitive process of working at living a more secured and bountiful life. The workings of early man in these directions approached application of thought and led to laws of such operations, and hence, science. In these early stages of society, science was understood in terms of its application in day to day work, that is, in techniques. Individual techniques developed into technology. Formalization into science followed the more urgent need for techniques of survival and led to qualitative improvement of lifestyles. The processes and nature of this formalization in protohistory, however, remains a matter of conjecture, in the absence of written evidence. Application of techniques and technology were

evidently the direct concern of early man. What is important for studies attempting to graph technological and scientitic developments in early societies, is an empathetic approach towards understanding the cognitive evolution in human societies. Thus there is a necessity to correlate the developments that are noted in given contexts to the social requirements and emotive factors. The first factor that guided human action towards interference with nature is survival. The basic concerns were food and shelter.

The beginning of selection for hunting and storing live animals made up the earliest developmental stage. Selection of plants for consumption and seed plantation at random followed closely. This was the stage of cultural growth when men were also making the first ceramic utensils. It is at this stage of civilization that we find the first evidence of human activity in South Asia. Following this, at every stage of discernible development and change, it is the constant need for a better lifestyle that urged human cognitive advancement, reflected in human handiwork.

If one has to talk about the pre-Harappan society one has to begin with this backdrop to the pre-Harappan genre as found at Mehrgarh, a site in the Kachi Plains of Baluchistan, which revealed a continuous habitation from the seventh millennium B.C. to the second millennium. In this story of human social growth the workings of human mind in innovative, inventive and adaptive pursuits are the most essential factors contributing to the process. We are making an attempt to chart and analyse some specific elements in this drama of human cultural development from pre-Harappans (backdrop : seventh millennium BC) to the Harapan (third millennium BC).

At Mehrgarh (1) we come across the first stages of human innovation, especially in three fields of activity, between the sixth and the fifth millennia. Following an aceramic stage of occupation, there was the initiation of ceramics in period IIB. This development ran along with the adoption of animal species, their selection and breeding for domestication. The third was

the selection of wild plants and their domestication. The animal species that were selected were sheep, goat and later cattle, with a growing popularity of the latter. A gradual selection of domesticable species of animals and their adoption to a man-made environment, followed by breeding, is very well documented in bones at the site through two successive stages of cultural occupation. First, we note a gradual diminution of the bones of extremity in all the species associated with domestication, viz., goat, sheep and cattle. This size diminution is said to be an indication of gradual domestication of these species locally. Secondly, here is the earliest available osteological evidence of the wild Indian cattle, bos indicus, being domesticated locally. Lastly, we see a marked and growing preference for sheep over goat and a predominating popularity of cattle, which is a phenomenon common with the evidence at many other neolithic sites in the plains of South Asia. R. H. Meadow, who analysed the Mehrgarh material also studied the osteological evidences from the chronologically later Early Harappan sites of Balakot in Makran coast, Baluchistȧn and Jalilpur in the Western Punjab. He noted that even in these ecologically different regions the trend was similar. The cattle species dominated the domestic scene along with a marked preference for the sheep over goat (2). There appears to be conscious selection of those species which provided the maximum amount of meat and milk and those which were more suited to the environs in the river plains. The botanical evidence at Mehrgarh also reveal a simultaneous (aceramic neolithic-ceramic neolithic) selection and adoption of wild wheat and barley taxa for domestication. The biometrical study of the impressions of grains and the charred remains indicate that there was a gradual increase in the quantity of domesticated six-row naked barley as well as six-row naked wheat (Triticum durum) and a gradual transformation of the latter to an even better species of Triticum Sphaerococcum in the succeeding periods (3). Thus a stage by stage development is botanically preserved at Mehrgarh. Most significantly, cotton seeds have been recovered from Mehrgarh period II. The indications for weaving

is not clear at this very phase. However, the presence of terracotta spindle whorls widely found at several Baluchi sites, from c. 4500 BC onwards point to an early beginning of the textile craft, albeit in a rudimentary manner. As to the rudimentary technological endeavours we have to appreciate the use of stone sickles, with three bladelets hafted slantwise in bitumen, for convenient harvesting. It is evident that a number of specific tools, like the sickle, were being used, like the stone drill and the pottery wheel, by the period II. The most astonishing development is marked by the mudbrick structures which begin with the c. 6000 BC. The walls were made with regular sized mud bricks viz. 33 or 28 cm by 14.4 cm by 7 cm. The discovery of a number of stone, shell and bone ornaments not only reveals a colourful culture even at this very early stage but also indicates a layout of the society, which may have been a tiered one. Wheelmade pottery begins to appear on the scene along with handmade ones from period IIC, dated around c. 5000 BC and later. Thus as early as the fifth/fourth millennia the stage was set in Baluchistan, the region that has rightly been identified by D. K. Chakrabarti (3a) as an interaction zone between southern part of central Asia, the Indus Valley and Iran in the west. This would provide the social background and motivating links for further technological and scientific developments in the subsequent times throughout a greater geographical and social orbit.

The fourth millennium onwards there was a proliferation of settlements, seasonal and permanent, throughout the regions of Baluchistan, Sind, and Bahawalpur in the W. Punjab (4). There is a clear sequence of progress from crude handmade and basket marked pottery to fine wheel-turned pottery at some sites indicating a continuous and sustained development of ceramic technology. The introduction of wheel would prove to have a wide reflection on social life. It would not be long when rudimentary transportation would be fashioned from wheels. In fact the period I sequence at Gumla, a pre-Harappan settlement in the Gomal Valley, witnesses the introduction of both the wheelmade potteries and the wheeled cart, evident from the presence of the terracotta toy models found there. Other

technical activities like, stone bead cutting, rushing, weaving along with the beginnings of earnest crop farming and animal husbandry mark a stage in the greater Indus and Baluchistan that would provide the right settings for a growing civilization. It is to be noted, however, that there was no monolithic phenomenon of an universally common process of development. There were different strata of cultural existence and simultaneous adoptions of different lifestyles in different eco-geographical and ethnic zones. Yet there was, within a very loosely defined connotation of human "development", a kind of sustained progress of human life. For example, while the dwellings of wattle and daub were common, mud brick structures were also being constructed. These bricks were plano convex and sun dried. The technique of making bricks and ceramics manufacturing were closely linked, not only because of the commonality of the ingredient clay but also because of the drying technique. The development in ceramic manufacturing and brick-making occurred jointly with the introduction of fire and the construction of the kiln. The introduction of fired bricks and ceramics mark a new stage of technological development. In the sphere of food production, the introduction of selected species, suitable in the habitat, is evident from the fifth millennium, as already noted. But the quantification of this innovation in different eco-geographical zones, experimenting with different taxa, marks a further stage of advancement of human civilization in South Asia. Taking the Kashmir Valley(5) and the Ganga-Vindhyan region of the subcontinent, beyond the direct pre-Harappan zone(Baluchistan, Sind, Haryana, Rajasthan and Gujarat), interesting evidences regarding crop selection are available, which illustrate the case at hand. In the first instance there is the evidence of lintel and masur pulse having been consumed by the aceramic neolithic people around the third to second millennia. In the second instance there is the evidence of rice having been cultivated in the neolithic stage in the Ganga-Belan valley near Allahabad around the sixth-fifth millennia BC (6). Thus, it was not only the pre-Harappans of Baluchistan, Sind or the Punjab who were

ready for advanced farming but even the neolithic communities in the peripheries were trying to adopt nature and its resources. Coming back to the pre-Harappans, the conception of adaptability of various taxa of crops even within the Harappan zone had a reflection on the social and technological readiness of the pre-Harappans for a further stage of development. At Mehrgarh cotton and oats were introduced in the fourth millennium. Between fifth and third millennia BC. at Balakot (7), a pre-Harappan site in the Las Bela plain of Baluchistan, a variety of legumes and gourd have been indentifed. Cotton was also found at the site. At Tarakai Qila (8), in the Bannu basin, lentils and peas were found to have been cultivated. The third millennium BC evidence from the pre-Harappan sequence at Kalibangan in Rajasthan (9) marks the apex of the development in the realm of crop production, Here we come across a ploughed field, left intact with the furrow marks on a grid pattern. There are two sets of marks running at right angles to each other, aproximately north-south and east-west, respectively. The average distance between the individual furrows of the former set is 1.90 m and in the latter set the distance between furrows is 30 cms. The north-south furrows overran the east-west ones, indicating that the short spaced east-west ones were ploughed first. The evidence points to the system of double cropping probably, with mustard sown in the larger grid and horse gram in the shorter. This evidence for a mixed farming in a third millennium BC context is corroborated by findings from Rohira (10), a site in Punjab, where farmers of the pre-Harappan times were cultivating barley, dwarf wheat, lentil, horse gram and jowar. It appears that the pre-Harappans had come to grasps with the techniques of plough cultivation; double grid furrow for double cropping; particular species selection for double cropping; and the technical requirements for the production of multiple crops at selected sites. At the base of this growth in farming lay the inevitable demands of the growing societies in the different ecological and geographical regions, especially in and around the river valleys and plains. The demographic increase is reflected in the numbers and sizes of the settlements throughout Baluchistan and parts of Sind, Bahawalpur and

Cholistan from the mid-fourth millennium onwards, which perhaps led to the search for more spacious ambiance and a better life.

Apart from the adoption of a rich and varied crop pattern, the pre-Harappans were probably trying out their hands at water management, a term that we are using to describe certain features which cannot be formally declared as irrigation works. Let us try to describe the works first. The site of Amri, for example, lies in the valley of the river Hab where it flows through high bluffs. The Amri people occupied a spot at the edge of the plain close to the valley wall at the back. Now, behind the front range of this valley wall an extensive natural catch basin was formed. This is the exact location where the water came from the mountainous torrents at the higher reaches of the river and got deposited in a natural basin, especially during rainfall. There was a gap in the valley wall originally, through which the water used to flow out. However examinations reveals that this wall was artificially sealed with a stone block dam, 25 ft thick, thereby forming a complete reservoir. According to archaeologists like W. A. Fairservis (11) and N. G. Majumdar (12), this was formed by the pre-Harappan inhabitants of Amri. The impounded water in the reservoir was probably released at times through irrigation channels for cultivating the nearby fields. The surface remains of the site reveal other structures of stone, like thick walls, paved floors and stairs, Thus the beginnings of large scale contruction work for water management can be credited to the pre-Harappans. Again at the Nal culture site of Kohtras Buthi there are evidences of massive stone walls of boulders being constructed on the alluvial valley of the Baran river flowing nearby, across the foothill, to catch the silt. Not only did these artificial structures indicate a high degree of engineering skill achieved by the Nal and Amri people, who were associated with the pre-Harappan developments, but it also indicated the existence of a management system that presupposes an organised society.

Probably now the genesis of the urban Harappan culture seems to be a more real and palpable fact. From this stage it

was a short distance to the structures of mud bricks built for storage purposes. The motivation came from the instinct of preservation of valuable and rare things. The concept of defence of life and property evolved and the development of building techniques was closely linked up with this. Of course the technique of stone boulder cutting for stone bricks provided a model, yet the fashioning of mud bricks even earlier at Mehrgarh definitely points towards an early beginning of clay modelling. Given the topography of the regions where the cultural growth was concentrated mostly (all near major and minor river valleys), the aptitude of the people in resource management has to be lauded. The evidence from pre-Harappan Kalibangan (Pd-1) would illustrate the point (13). At this stage we find a fortification wall made of mud bricks, 30:20:10 cm, proportion being 3:2:1 and 40:20:10, i.e., 4:2:1. The smaller bricks were made later. Within this enclosed area five to six massive platforms made of mud bricks were constructed. Besides this, two stages of structural activity is attested by the remains of both domestic type as well as the citadel complex. Most interestingly, baked bricks were being used in drains. Lying on the left bank of the Indus, the pre-Harappan complex at Kot Diji (14) is marked by a massive defensive wall. The lower courses of this wall were made of limestone rubble and the upper part was made of mud bricks. It was strengthened by bastions. Here the house walls were made of both mud and stone bricks. Rahman Dheri (15), another Early Harappan site in the western plains of the Indus also has a massive defence wall built around it. At this site we have perhaps the kind of planned settlement that was later to become the hallmark of the Harappan civilization. The aerial photograph of the site shows an extraordinary regularity of layout. The site appears to be of an oblong shape, surrounded by a massive wall of mud brick. The enclosed area is divided into two portions by a street running north-west to south-east. The houses lay at right angles to this road. They were divided by regular, straight, narrow lanes. Dated to the first half of the fourth millennium, the findings at Rahman Dheri are a postscript of the developments that took place at

Mehrgarh in the fifth millennium. On its part Rahman Dheri stands as a precursor of the well-laid out cities of Mohenjodaro, Harappa, Lothal, Banawali, Dholavira and others, perhaps still awaiting the archaeologist's spade. A continuation of these trends of development is evident in the succeeding genre of the Mature Harappan culture.

The kind of precision in planning and execution indicated in these activities can also be found in the parallel developments in the ceramic industry and in the firing techniques. All this is more evident in the Mature Harappan phase. The application of chemistry was an unconscious ancillary in the processes of brick, ceramic and metal manufacture. The scientification that took place is not borne out by records. But the technical feats revealed in the artifacts speak volumes for applications in technology. The prevailing colours of the bricks, pottery and miscellaneous terracotta objects at the Harappan sites in the Indus valley are light red or salmon. Chemical analysis showed that the colours were due to the presence of iron compounds in the clay and the kind of firing they received (16). The reddish colour is achieved in a close kiln where oxidising atmosphere is generated. The pottery as well as the bricks of the Mature Harappan were very well done. E. H. Mackay (17) observed that the bricks at Mohenjodaro, for example, were of an excellent quality, well burnt and practically indestructible. They could be used over and over again. The pottery fabric was also hard enough to withstand considerable knocking around and emit a metallic sound. A very efficient firing technique is indicated in both instances. Mackay has reported two pottery kilns from Mohenjodaro (18). The diameters at the top of both measured some 3 ft 3 in., whereas the flat base of the kilns was measured 2ft. 10in. in diameter in case of one and 3ft. 2in. in the other. The depth of both kilns was 4ft. 3in. They were paved with bricks, and round the inside of each was a 4-inch ledge. The top of the Kiln was only slightly above the door on the side. The vitrification of the inner mud walls of these pits shows that they were used to fire articles at a very high temperature. The

fuel used was either wood or charcoal. The ledges were probably intended for the support of a crucible. According to Mackay the kilns were used for objects more fusible than copper because of their lack of draught or vent in the lower portions. However, one cannot be definite about their purpose. In fact, K. T. M. Hegde holds the view that most of the Harappan pottery were open fired (19). We may assume that there was a planned use of different types of kilns both for firing of clay and metals. For, at Harappa three types of furnaces have been found which might have been used for metals. They were, (a) round, (b) cylindrical pits dug into the ground and (c) pear-shaped pits. All, with or without brick linings offered an uniform firing and provided the scope for intense firing. Repeated mud plasterings gives an indication of repeated use (20).

Technological development was, however, not only a result of need but also of pleasure. The pre-Harappan and Harappan pottery exhibit an aesthetic use of art which also required some techniques. The application of different slips and colours on pottery reveal a tradition of experiments with different minerals and organic materials for creating colours. Cream slip was applied with the use of lime, black from lamp black or powdered charcoal, chocolate and purple slip indicates the inclusion of manganese, pink and red was achieved by using red oxide (21). The technique of making glazed ware marks a further stage of development in this direction. According to some scholars the Harappan glazed wares, also called the reserved slip ware, are the earliest such specimens in the world (22). The application of a burnish was followed by the application of silica, soda and potash in the form of crushed quartz or pure white sand and a glassy flux and other colouring agents. Then a portion of both glaze and slip were removed by a comb-like object so as to leave a straight or wavy decorative mark on the pottery. Finally the required effect was achieved by an efficient firing. Scholars differ widely on the question of the Harappan glazed pottery. Some, like Mackay himself (23), hesitate to call them true glass or even true glaze like F. R. Allchin (24); while others discern the beginnings of glass technology in this development (25).

H. D. Sankalia (26) has discerned a five stage preparation of the glazed ware and D. K. Chakrabarty (27) is of the opinion that this pottery is of no extra Indian origin.

There are so many evidences of fine working on the part of Harappan craftsmen that the question of tools come in. To mention but a few such cases : the innumerable patterns painted on the Harappan pottery; the cutting and engraving of seals; the cutting and boring of beads; the measuring of bricks, walls and buildings, all required the conceptualizing, fashioning and subsequent use of precision tools by the Harappans. The intersecting circles, triangles and squares painted on the Harappan pottery required not only a knowledge of geometry but some instrument such as some primitive counterpart of compass and scale. The seals were first cut with saws, obviously of fine proportions. Then the boss was shaped with a knife and bored from either end (28). The carving of animal motifs was done with a metal burin. The Harappans used both metal and stone drills for making beads (29). The use of such instruments presuppose a volume of scientific experimentations catering to the workman's needs.

The evidence of number of precision tools made of stone and the gradual entry of metals via use of metallic ores along with stones near pottery or brick kilns, point to another aspect of technical advancement. This in fact, was an inevitable and integral part of the all round social development taking place at some of the sites in the early, pre-Harappan days. Later, we find metallurgical processes being tried out by subaltern cultures individually, especially among some chalcolithic cultures in Rajasthan. A survey of both the early and the later (chalcolithic context) attempts at metallurgy reveals much about the contributions of these 'lesser' cultures in developing rudimentary processes. In face of these evidences the theory of pure diffusion of metal technology from Mesopotamia or Iran receives a jolt. As in other respects of innovation, the first pieces of copper, a ring and bead, along with a small copper ingot, so far recorded also occur at Mehrgarh, period II, as early as the sixth-fifth

millennium BC. The excavator, J. F. Jarrige points out (30) that at this stage the craftsmen at Mehrgarh were only hammering and polishing the native copper. The period III levels at the site has, however, yielded a few crucibles containing traces of copper. This indicates that a definite improvement in technique must have occurred resulting perhaps in the smelting of copper around the fifth millennium. From fourth millennium levels onwards, bits and pieces of copper, though rare, begin to appear at several different cultural sites in the Baluchistan, Afghanistan, Sind and the Punjab. Whether this development resulted from a network of contacts with Mehrgarh and Mundigak (chalcolithic, Afghanistan) or from the general experience of the emergence of cultures over these wide areas, is a question difficult to resolve. The metal pieces, by their paucity and very character, reveal the fact that it was the powers that be, in each of these settlements and cultures who used the metals, probably as symbols of power and status. The minor amount of daggers and knives speak of personalization and the rings, rods, hair pins, discs, bangles etc. were all parts of the accessory for display of social position. While the status of the users could thus be identified as belonging to the upper echeleons, the smiths who were experimenting with metals, were far from that social enclave. In any area of technological expertise it is essential to identify the repositors of that knowledge. So far as technological advancement is concerned, the early metal smiths were applying the processes of hammering, bending, grinding and polishing. All these required a great accumulation of experience and knowledge. The next stage was marked by the process of annealing, which requires the heating of the metal above its re-crystallising temperature, which in case of copper was 590 C. The pottery kilns served an important purpose here. It was one step further to the stage of smelting. The pottery kilns sufficed at first but soon they were replaced by crude blast furnaces built by metal smiths. Clay crucibles were used for the purpose. Smelting took place in wood or charcoal fire over a clay-lined pit with channel for air. The metal smiths were experimenting with a number of metals, like silver at some Nal culture sites(31).

The social evaluation of technical knowledge in any given context gets closely and inevitably interlinked with the processes of politicization of social ranks. The nature of the settlement lay-outs of the major Early Harappan as well as Mature Harappan cultures clearly indicate the probability of a class-divided society. It would be important to discern where, within such stratified society, did the scientific endeavours got nurtured and generated. In spite of the lack of literary data, one may plausibly assume that it was the smiths in any sphere of handicrafts, who developed their own rules of operation closely conditioned by their workshop ambience. These rules then were standardised and spread over a wide geographical region via the operational network set up by administration. It is difficult to evaluate the exact manner of scientification of technological processes at this stage of South Asian protohistory. It is equally difficult to identify whether the theoretical aspects of these technological processes were handled exclusively by the smiths or whether there was a parallel intellectual elite supplementing theoretical knowledge. However, there is no doubt about application of technology by the smiths themselves, sometimes even at grassroot levels, as in the case of Rajasthan copper smiths or Rohri-Sukkur flint blade makers. This understanding of the ambience of technological experience is important to answer the question whether a breakdown of the administrative structure would not immediately and necessarily result into the total loss of technical knowledge. Now, there is a firm ground to believe in a continuity of the technical expertise in a post-Harappan era.

Between the fourth and the third millennia, a great degree of human mobilisation took place throughout Afghanistan, Baluchistan, Sind, Punjab, Rajasthan on the one hand, and the Iranian Plateau region, Central Asian plains, across Iran into Sumer Mesopotamia, on the other. Trade was a great vehicle of this mobility. Another was pastoral migration. In this movement of people the larger domestic animals like camel and ass, but more substantially, cattle, played a major role. The use of wheeled vehicles attached to these animals is attested by the presence of terracotta toy models of wheels in the pre-Harappan

assemblages. This is followed by the findings of full models of toy carts among the Mature Harappan assemblage. These movements of people helped develop inter-regional contacts and cross-cultural interactions. The result was seen in a widening of the sphere of each culture and each region. The resource bases extended beyond the natural regional boundaries. Besides this, diffusion of ideas, faiths, customs and technologies created a cultural basis for intellecual efflorescence. The Mature Harappan cultural grandiosity was built on this edifice.

The indications of this cultural growth are seen in the magnificent city planning of the metropolises, exhibiting grand structures constructed of precisely manufactured mud and burnt bricks. The prudent use of both types of bricks reveal resource efficiency. At Mohenjodaro (32) sun-dried bricks were used mainly for fillings. But at Harappa they were sometimes used alternately with burnt brick, course by course for building walls. At Kalibangan (33) burnt bricks were exclusively used for drains, wells and bathrooms. Thus a profile of cities and their residents emerge from the techniques employed to build them. The predominant brick size was 28 by 14 by 7 cm, the ratio being 4:2:1, as seen in the pre-Harappan complex. The bricks were generally made in an open mould. But for special purposes, especially for bathrooms, sawn bricks were invariably used. Special wedge-shaped moulded bricks were manufactured for wells. At Mohenjodaro many lanes and streets had brick drains covered over by bricks or stone slabs. The street drains were equipped with manholes and sometimes flowed into soakage pits. The Great Bath at this city is a wonder of architectural feat as is the Great Granary at Harappa (34). The Dockyard at Lothal is yet another construction worth to be mentioned (35). The Gateway and columns at recently excavated Dholavira (36) reach the much later but much lauded Grecian standard. What is important in all these wonderful achievement is the perfection reached by the Harappans in calculating and measuring of lengths, breadths and depths, in other words, mensuration. So far as the development of the sciences of geometry or mathematics are concerned, there are certain evidences offered

by M. N. Deshpande (37) and Debiprasad Chattopadhyaya (38) that the standardisation of brick measures, the geometric measure followed by seal cutters, the skilful construction of fortifications, the building of the granary etc., the precise concentric circles drawn on pottery, are all indicative of such devolopments. The reports of Mackay (39) Vats (40) and Rao (41), describe measuring scales found at Mohenjodaro (shell), Harappa (bronze) and Lothal (ivory). The bronze scale from Harappa was analysed and Vats reports that the value of the divisions on the scale was found to be 0.3676 in. on an average. This value is found to be half of 0.737 in, which is the value of a digit or *zeb* in the Egyptian system of length measurement. Four such digits make *shep* or a palm of the Egyptian system, the value of which is 2.947in. Seven such palms makes a *meh* or cubit of the Egyptians equaling in value to 2.62in. This unit of measurement was termed the 'Royal Cubit' and is found to have occurred far and wide in many early civilizations. It was in use in Egypt since predynastic royal tombs; in Babylonia as 20.89 in and even in New Mexico as 20.68 in. as well as the English stone circles as 20.55 in. Vats offers the evidence of actual use of this system in the buildings at Harappa and Mohenjodaro through a number of checks applied by measuring houses, rooms, courtyards, streets, platforms etc. There is another line of thought as to the linear measurement system of the Harappans and E.J.H. Mackay discusses both the possibilities. According to Mackay, the Mohenjodaro scale could also have been fashioned to the decimal system. He observes that "on the basis that every man has ten fingers it seems to me that the decimal system should be more primitive than the sexagesimal system and that it may have had an independent origin." The Mohenjodaro scale has 9 graduations. There may have been a tenth graduation of the scale originally. There is a hollow circle on one graduation followed by a large circular dot after five graduations. This sequence indicated that a hollow circle would occur five graduations after the dot followed by a dot after five more graduations and so on. It appears that the first is the minor graduation while the second is the major

graduation. Now the distance between the two lines of minor graduation is, on average, 6.7056 mm. The length contained between five such graduations is approximately 33.528 mm. The length between two marks of the major graduation is therefore, 67.056 mm. approximately. As mentioned earlier, the scale is likely to have had ten major graduations originally, the total length of the scale thus being 670.56mm. This is practically two-thirds of a metre. It also appears that the length scale is decimally divided. The ivory scale from Lothal is 15 mm broad and 6 mm thick. It is available in a length of 46 mm. Twenty seven lines of marks are visible on the scale in a length of 46 mm. The average distance between two lines comes to 1.7 mm. Twenty such divisions are almost equal to the distance between one circle and one dot on the Mohenjodaro scale i.e., 33.46 mm. The Mohenjodaro unit of 67.056 mm. is therefore, roughly equal to forty divisions on the Lothal scale. Thus a link has been established between the two scales. The Lothal one was more minute and appears to bave been useful for minute measurements. According to S. R. Rao even the smallest Indus seal can be accurately measured in terms of the divisions on the Lothal scale. Mainkar's analysis shows (42) that the bricks used in the Harappan cities were made in dimensions which were multiples of the large graduation in the Lothal scales, the unit being 25.56 mm. The sixth and the twentyfirst graduation lines on this (Lothal) scale are longer than the rest, making up perhaps the major or larger graduation. The length between these two lines, which is equal to 16 minor graduations of the scale, is 25.56 mm. One of the brick types from Mohenjodaro has a length of 225 cm., which is nearly equal to nine times the major graduations on the Lothal scale. Similarly, other brick types have also shown to be corresponding to either the Mohenjodaro or the Lothal scale. Whatever the value of the scales, it may be assumed that the bricks were made in accordance with a fixed scale of measurement.

As to the weights of measurement, rectangular blocks of tawny, or grey chert and hard rocks like gneiss, mostly cubical but in some cases cylindrical, well finished and polished, formed

the pieces of weight used by the Harappans. The stone weight from Harappa, Mohenjodaro and Lothal and other sites vary in size from 1.1x1.1x0.7 cms to 4.1x4.1x3.4 cms. The mean weights of the various groups are found to be in the simple ratio of 2, 4, 6, 8, 32, 64, and 120. Hemmy (43) who analysed the weights from Mohenjodaro and Harappa found that the system followed by the Harappans was partly binary and partly decimal. The weights from Lothal have also been found to have been binarily ordered (44). In fact S. R. Rao observed that there were two sets of weight at Lothal, one roughly corresponding to the mean value of the *shekel* in the Heavy Assyrian system used at Susa, namely, 8.37 gms. Rao thinks that the Lothal merchants might have used this standard for trade with the external world, reserving the other for transactions within the Harappan zone. Mainkar however, argues against the classification of Harappan weights as partly binary and partly decimal. A careful observation of them, according to Mainkar reveals the fact that they followed the decimal system in weight also. There may be disputes as to the exact ratio or system followed by the Harappans as to both length and weight measurements. However, their systematic computation and use for technical work is beyond doubt, which speaks volumes about the kind of mathematical and computing ability nurtured in this early civilization.

By the days of the Mature Harappan culture the metal smiths had made much progress at least, quantitatively, in the sphere of metal crafts (45). They were handling multiple metals—bronze, gold and silver. The abundance of the metal artifacts at the metropolises as well as the occurrence of substantial amount of silver denote affluence, trade exchanges, efficient distribution of raw materials. All these are features of a highly developed and organised control mechanism. Copper came into the Harappan metropolises from Rajasthan mines, some copper, lead, tin and silver came from Afghanistan, extreme west of Baluchistan and Persia. Precious and semiprecious stones came from Badakhshan and the Gulf regions. Gold came from the Himalayan rivers and the neolithic Karnataka. One can clearly

categorise the different metal objects manufactured by the Harappan smiths, viz. tools and implements like knives, chisels, razors, saws, fish hooks, sickle shaped blades, needles, awls, reamers and metal rods. Next come the metal utensils, mostly of copper, some silver, in the larger metropolises. They comprise jars, dishes, bowls, offering stands, vessels with handles, etc. These were mostly modelled on the ceramics. The third category is that of weapons, so called because of their identification with modern-day blades. These could have served purposes other than defence. Axe blades, spear heads, daggers, arrow heads and lances have been identified. The fourth category are the most minutely made jewellary using copper and gold and sometimes combining terracotta and semiprecious stones. They consist of finger rings, earrings, bangles and necklaces. Besides there were a number of miscellaneous objects. The casting and minute soldering required a great degree of precision and skill. In the sphere of metals as well as in the sphere of ceramics and brick manufacturing, the technique of firing contributed a great deal. The smiths had developed the kilns and a few examples are available to us. The matter of bronze alloying was not always a deliberate application of technology. The presence of the required amount of tin, arsenic or lead for accidental alloying could be due to trace elements and impurities. However, the repeated use of those very ores from the specific sources, which produced the harder, sharper metal and contained these impurities in their natural form, may not have been accidental but deliberate choice. The question of diffusion of metallurgy from outside South Asia has been shelved. But the question remains whether or not to regard the evidence for local metallurgical experiments from some contemporary non-Harappan 'lesser' chalcolithic cultures, especially located in Rajasthan, as having contributed to the total process of metallurgical experimentations. As already raised once in connection with the experiments with plants, the hypothesis of the participation of the numerous 'other' neolithic and chalcolithic cultures in the genesis of qualitative changes in early social existence in the South Asia has to be reviewed. The

data from these non-Harappan chalcolithic genres have to be juxtaposed with the mainstream Harappan experience. This kind of exercise could provide clues to the continuity of earlier Harappan-contemporary technological traditions in the late and post-Harappan phase, kept alive by a number of ancillary cultures, albeit in a 'devoluted' form. The peeling away of the urban veneer from the fabric of the Mature Harappan culture did not automatically entail the loss of technology and science, although the high water mark of application may have been less and less evident.

The Harappan art is developed best in the making of seals, a distinctive feature of the culture. Most of the graffiti, which is actually the writing of the people, is also found on these seals. These were small in size, carved intaglio, generally on steatite, or grey stone, often glazed white with the heated and fused dust of the parent goods. They contain pictures of animals mostly along with a few signs (46). The other objects, which bear Harappan writing besides seal impressions, sealings and moldings are pottery fragments, copper bronze tablets, inscribed ivory and bone objects. But the seals are the most important. About three thousand pieces of seals have so far been recovered from Harappa, Mohenjodaro and other sites. The seals may best be described as very small objects or miniatures inscribed with simple messages. They have predominatingly animal motifs. Since the time they have been discovered, a number of scholars from all over the world have tried to decipher the Indus script. But so far none of the attempts at decipherment has met with universal approval, nor do they satisfy all conditions. The Indus script remains an enigma. The writings are a combination of animal devices, characters and signs as well as scenes of Harappan life or mythology. The technical problems like the lack of bilingual inscriptions, the small length of each of the inscriptions, the small number of seal impressions, as well as the cultural context itself, impedes the way of its unravellment. Established scholars have linked the Indus script with Egyptian hieroglyphics, Hittite and Chinese writings, respectively. A number of links were extablished with a proto Dravidian (47)

or a proto Aryan language (48). There is very little agreement among scholars concerning the writing system. A number of them seriously point out problems in the way of categorising the seals as having served any single, specific function, breaking down the notion of a seal-based administration (49). At this stage of research it may only be possible to assume that the Harappan people had developed a manner of graphic signs, which carried some meaning or message for the users at both ends of a function. The fact that this probably developed through a very long period of time is attested by the evidence of potter's graffiti commonly occuring on the Amri (50) and the two Indus type seals at Nindowari, a Kulli cultural site in the Kolwa tract in Baluchistan around mid-third millennium BC(51). However, in the context of the Mature Harappan culture, there is little evidence of a widespread popularisation of the script. This scarcity of evidence could be due to the use of perishable materials for writing at the more popular level. Thus it does not necessarily mean a restricted use of the script by Harappans. But so far as the attempts of decipherment are concerned, the small number of seals and the sealings spelt problems in the way of analysis. It could also indicate that the small number of seals and sealings were probably not used to make a huge number of impressions. It is probable that their use was restricted to a few class of people or for a few purposes, although the script itself was more commonly used, probably on perishable materials. In fact, at present there are new opinions emerging as to whether these seals and sealings were at all important in administrative work in Harappan culture. But it remains an empty conjecture at the face of the as yet uncomprehended problem of the Harappan script . Yet, the significance of the script cannot be minimised. There is enough evidence that the Harappans had developed a kind of script to put across messages, whatever their nature and purpose, which had been uniformly prevalent throughout the farflung area that was the Harappan orbit. It therefore, marks a stage in the cognitive development of these people. It would not be wrong to agree with G. L. Possehl (52) that it is premature to conclude that there is little

to be learnt from the analysis of the Indus script. And although the script seems to have not evolved fully with the Harappans, its continued assimilation and absorption in later scripts of South Asia cannot be ruled out.

There is now a volume of evidence, as we have referred, pointing to, a graduated evolution of technology within the peripheries of the Harappan Culture through a long preceding period. However there was definitely a process of ongoing dialogue between the technical presonnel and peasants of different regions or even contemporary other cultures, via trade and merchandise distribution which may have influenced and improved certain work modes. In the primary production sector the Harappans brought in more crops. A mixed herding-farming economy is sometimes encountered near some metropolises. The number of taxa increased, especially with the Harappan foray into Gujarat. The Gujarat Harappans selected and initiated the cultivation of rice. However it is in this most important sector, i.e, agriculture that the graph of development does not show a spectacular rise. This is partly due to the constraints put by the topography. Neither did the Indus or the other rivers near Harappan sites produce a sheet flood which stands for weeks, nor was there the topographical advantage of gravity flow canal irrigation during the months that mattered most for crops to grow, from November-December to April-May. As Shereen Ratnagar (53) points out, the Harappan farmers took recourse to well irrigation, labour intensive cultivation and periodic, small scale cultivation on flood plain. The evidence for intensive plough cultivation being continued in the Mature Harappan phase along with the practise of canal irrigation is encountered at Shortughai, one of the gatepost settlements of the Mature Harappan culture in the Oxus river region. With all the constraints it is a wonder that the Harappans could create a support base for an urban culture over such a wide ecological geographical orbit. A slight imbalance in climatic and ecological factor or a break in the distribution chain could severely affect the line balance on which the culture rested. Thus it was rather a combination of factors like this, which altered the pattern of

nexus and the superstructure crumbled by bits. The legacy of much of the technology was handed over, the evidence of which is now being discerned by scholars in the socio-economic genre reflected in the Later Vedic texts. Here a clear assimilation of earlier non-Aryan culture is evident which gave colour to the way of life in South Asia subsequently..

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Author's Note :

The terms Pre-Harappan, Early Harappan and Mature Harappan qualify certain cultural genres. They have been alternated with other terms too, like Early Indus, Mature Indus, Indus-Saraswati etc. It is for the convenience of discussions that some manner of designation is sought to be applied to the contexts to contain their specificities. This aids a holistic approach to cultural studies.

Pre-Harappan actually covers the multi-cultural scenario in Baluchistan, Sind, Punjab and some parts of Haryana, even Gujarat and Rajasthan, but primarily the first two regions. It takes into account the early farming communities and their activities from 4500 BC - 3500 BC.

Early Harappan is a more sanguine and specific designation for those cultural enclaves and communities that continued into the Mature Harappan phase i.e., 3500 BC - 2500 BC.

These terms are very broadly used to define the overall contextual paradigms and are not significant by themselves.

II - 2

PHYSICO-CHEMICAL IDEAS IN ANCIENT & MEDIEVAL INDIA

C. K. MAJUMDAR

I

Physics is the science of measurement. It is concerned with motion in space and time. It is also the science of energy and deals with the interaction of radiation and matter. Chemistry is the science that deals with elements, their properties and their combinations into molecules, that is, with the constitution of matter. Organic chemistry deals with molecules based mainly on carbon and a few other elements like hydrogen, oxygen, nitrogen, sulphur and phosphorus. Biochemistry studies molecules—sometimes big ones or macromolecules—involved in life-processes. Such specialization is quite modern. In the past there were strong overlaps among specialized branches of today. Physics had overlaps with geometry, astronomy, mathematics and chemistry. The description of chemistry given above is post-reductionist, when we have reduced all chemical substances first into molecules and elements and atoms. Earlier chemistry was more phenomenological and more descriptive. It dealt with solids, liquids, gases, minerals, gems, soil, wood—almost anything—overlapping with physics, geology, minearlogy, metallurgy and gemmology. Another motive for chemistry was search for medicine : there chemistry overlapped with botany, zoology and physiology.

Here I shall try to avoid overlaps of physics and chemistry, as defined today, with other specialties again as defined today. The major references that I consulted are listed below [1-6].

A word about chronology. I shall consider proto-history, the Indus Valley Civilization (IVC) with its ramifications, the Vedic and the Epic periods, the important imperial dynasties and kingdoms, right down to the destruction of Nalanda, Vikramasila and Odontapuri around 1200 AD as the ancient period. From that time to the founding of the (Royal) Asiatic Society in 1784, I shall consider the medieval period. The ancient period could be divided into two parts : in the earlier period, no written record exists or the written records that exist have not been deciphered to everybody's satisfaction; in the later period written records are available and can be examined and interpreted.

II

Sources of the History of Science

Written records, when they exist, are best sources for examining the ideas prevalent at a particular time of history. From the Vedic period onwards, there exists a vast literature in Sanskrit, Prakrit and Pali often addresed to scientific questions in astronomy, medicine and chemistry. Because of the literary conventions followed in these texts, nothing much can be learnt about the writers, and dates of composition are difficult to determine. When scientific ideas are presented in a particular religious or philosophical context, there are hermeneutical complexities. Still these records are extremely valuable. There are also written records by foreigners in Greek, Chinese, Tibetan and Arabic. Many manuscripts in the later ancient period is due to Al Biruni who was a distinguished scientist himself.

An interesting feature in the Indian history is the epigraphic evidence. The rock edicts by King Asoka are most famous; other numerous inscriptions on stones or on metallic plates are available.

Numismatic evidence is also useful : coins not only tell us about historical events and personalities, but their metallurgy

reveals chemical processes of metal extraction and metal handling.

In the medieval period, records in Sanskrit, Persian and other Asian languages were supplemented by accounts from European travellers and businessmen.

Of the IVC, no written records exist and the scripts have not been satisfactorily deciphered. So all the archaeological findings have to be analyzed : seals, statues, pottery, beads, gems, jewellery, household artefacts, cloth fragments, foodgrains and so on. In such analyses, modern scientific methods are often used. Students of the history of science must have some idea of these methods, their capability and their limitations.

Scientific methods of analyses of archaeological findings

Scientific methods which do not destroy examined samples are most useful. All of us know the famous story [7] of the Greek scientist Archimedes who was asked to establish the purity of gold used in a crown without breaking it. He found the solution of the problem in a bath and shouted 'Eureka'. The method is based on the fact that every pure substance has a fixed density at a fixed temperature. The crown immersed in water would displace water of equal volume; hence the known density of pure gold would give the weight of the crown if it were of pure gold, and any deviation would imply mixing of baser metals. Archemedes, in fact, found the general principle of buoyancy, which was not known in India. Density measurements on coins would certainly supply a lot of information.

^{14}C dating

The most important technique for fixing the age of archaeological object is radioactive dating in particular ^{14}C dating. Carbon has two stable isotopes $^{12}_{6}C$ and $^{13}_{6}C$; nitrogen has two stable isotopes $^{14}_{7}N$ and $^{15}_{7}N$. Nitrogen is a major and carbon dioxide (CO_2) a minor constituent of air. Neutrons ($^{1}_{0}n$) are produced in nuclear reactions in atmosphere with protons

in cosmic rays, and they react with nitrogen to produce the unstable isotope $^{14}_{6}C$:

$$^{14}_{7}N + ^{1}_{0}n = ^{14}_{6}C + ^{1}_{1}H.$$

This carbon reacts with atmospheric oxygen to form CO_2 which is used by plants in photosynthesis to make glucose. The glucose is used to build starch, cellulose, proteins and other materials in plant. All plant tissues thus contain traces of $^{14}_{6}C$. Animals eat plants and they too contain traces of $^{14}_{6}C$. The half-life of $^{14}_{6}C$ is 5730 years (the earlier value 5568 years has been revised); that is, half the *number* of $^{14}_{6}C$ atoms will have decayed in 5730 years. If the plant or animal is alive, a natural balance exists between the intake of radiocarbon and that lost by decay. The steady state implies about 15 disintegrations per minute per gm of carbon. When the animal or plant dies, the intake stops but the decay continues, and a very old sample of wood will have less radiocarbon than a recent sample. In one technique a very small part of the sample is burnt in oxygen and the CO_2 produced is introduced into a suitable counter. By carefully measuring the present rate, it is possible to calculate how long ago the plant or animal died. This provides an absolute scale for dating objects of plant or animal origin between 1000 and 2000 years.

Care must be exercised to avoid sample contamination while it is collected in an archaeological excavation. We mentioned the recalibration of the half life of ^{14}C. The other important assumption is that the ratio $^{14}C/^{12}C$ in the atmosphere is $1/8 \times 10^{11}$: this might not have remained constant over ages.

A variant of this method is based on accelerator mass spectrometry. It counts directly the number of ^{14}C atoms in the sample instead of waiting for them to decay. The samples required are much smaller than in the carbon dating method. The accelerator method requires identification of a single radiocarbon atom in more than 10^{15} normal carbon atoms ; this is not possible in a cyclotron, but has been successful in an electrostatic accelerator (e.g. the pelletron in Bhubaneswar may be used.)

Without going into details, some non-destructive techniques may be mentioned :

i) Neutron activation analysis, easy to carry out in the vicinity of a nuclear reactor; this is useful for trace element analysis.

ii) X-ray fluorescence : high energy x-ray knocks out electrons from the inner-most atomic shell, then electrons from outer shells fall back emitting low-energy characteristic x-rays useful for trace element analysis.

iii) Thermoluminescence : some materials exposed to radiation store energy in internal traps which empty when the substance is heated, releasing energy in the form of light.

iv) Ultrasonic studies for measuring elastic properties and strength of materials.

v) Electron diffraction, transmission electron microscopy, scanning electron microscopy, high resolution electron microscopy for lattice imaging : these reveal microstructure of metallic objects and therefore the treatments given to the metals in preparing the object.

In using these techniques experts should be consulted to assess the capability of the method, the accuracy of measurement, and interpretation of the results. Many of these techniques are available in Indian laboratiories.

For analysing objects from IVC these techniques have been of great help. Other standard chemical techniques exist for estimates of various chemical elements present. Another commonly used technique is atomic absorption spectroscopy. All archaeological finding of chemical interest are examined by these methods and quantitative estimates found.

III

Space : astronomy and geometry

Almost all notions of space, time and motion were formulated

by ancient Indian scientists on the basis of astronomical observations. The word 'planet' means a wanderer, so Sun, Moon, Mercury, Venus, Mars, Jupiter and Saturn were seven luminous planets in the sky. There are two invisible and dark planets — the two points of intersection of the moon's instantaneous orbit with the plane of the ecliptic. Eclipses can occur at these two points; that is how they were revealed, and they too wander in the sky. The motion of a planet in the sky, observed from the earth, is very complicated. The motion may be faster or slower than the average, halting, retrograde or zigzag. Ancient astronomers tried to explain these observations from a geocentric standpoint.

On the basis of astronomical observations, especially the eclipses, Aryabhata proposed that the earth was a spherical object suspended in space and rotated about its axis. The bold proposal caused a great deal of controversy in India. On the smaller scale, local properties of space were studied in geometry. As the word implies, geometry arose from the needs of agriculture, but it was important for the construction of altars and other religious rituals. The Pythagorus theorem, of which more than two dozen proofs are known, was also known to the ancient Indians.

Let us now examine how physical quantities were measured.

Fundamental measurements : mass, length and time

The measurements in physics can be reduced to those of three fundamental quantities : mass, length and time [8]. Here the electrical quantities can be left out, as they were unknown in ancient and medieval India. To-day the unit of mass is a kilogram, which is fixed arbitrarily. The unit of length is a metre, which is related to a certain wavelength of a stabilized krypton (Kr-86) laser. The unit of time is no longer related to the revolution of the Earth round the Sun, but is related to an atomic clock — to a radiation of a cesium -133 clock [9]. One second is 9192631770 periods of this line. Very recently the velocity of light has been declared to be exactly

$299\ 792\ 458\ \mathrm{ms}^{-1}$

so that the metre is the length of the path of light in vacuum during a time interval of 1/299792458 of a second. The tendency now is to relate a fundamental unit to a measurable physical quantity.

a. Mass

The principle of weighing was discovered in early civilizations — witness the constellation Libra in the zodiac belt. Evidence of metallic scales, copper pans suspended from a bar of wood or brass, was found in the IVC, and well-formed weights were also found. S. Sen [1] says that the standard weight was 13.64 gm, and its divisors by 2, 4, 8, 16 (powers of 2) and multiples by 32, 64, etc. were in use. A. K. Biswas writes [5a] (p. 101) : "A. S. Hemmy showed that most of the weights from Chanhu-Daro fall in the series 1 (the smallest weight viz. 0.856 gm.), 2, 4, 8, 16 (the standard weight viz. 13.625 gm.), 32, 64, 160, 320, 640, and 1600. The ratio 16 (sodasi) has been unique in the Harappan as well as the Vedic civilization (Prasna Upanisad, Jataka, .. etc.)". A division of the standard currency, the rupee, in such powers of 2 was current in India even in the 20th century, and the notion is prevalent in common Indian languages.

Why the weight 13.64 gm. is most common has not been explained. I have not been able to find a rationale so far. The choice, like that of the kilogram, is arbitrary.

In medieval India Alauddin Khilji tried to fix the prices of commodities — so standardization of weight was also necessary [6].

b. Length

About length measurement, S. Sen [1] has given an example in the IVC of a scale divided into five parts, that is, in the decimal system. Whenever geometry was used — in making altars, for example — accurate length measurement was necessary and would be done. Confusion exists in measurements of large distances. Longer distances were measured in kros (about 2 miles) and Yojana (4 Kros, i.e. 13 kilometres) [10]; notice the

powers of 2. Others take a Yojana to be about 5 miles or 8 kilometres (S. Sen) [1]. The Ramayana mentions that the bridge to Lanka was ten Yojanas wide and hundred Yojanas long [11]. Whether we take a Yojana to be 8 or 13 kilometres, the dimensions are far too large. In the beautiful, graphic account of the flight back to Ayodhya from Lanka, Kalidasa [12] avoided mentioning length or time. Often a distance was measured in terms of time taken to cover it (the practice is found in rural India even today), but this was not accurate.

Measures of volume and capacity were also known and are described in the HCAMI [3].

c. Time

The flow of time was understood very well. The growth of an individual from birth to death, the beauty and vigour of youth and their decline in old age, the rise and fall of kingdoms, their prosperity and decline in the course of time made a deep impression on the Indian thinkers. I need not repeat the well-known story of Siddhartha, as told by Asvaghosh [13]. The Mahabharatam has this tragic message [14]

All acquisitions decay, attainments decline,

Unions sever, and life ends in death.

Time flowing for ever is measure of all things and is regarded as the ultimate destroyer. In the Bhagavad Gita we have several interesting items [15] :

I am inexhaustible time (10.33)

Among measures I am time (10.30)

I am eternal world-destroying time (11.32)

Here are some more passages from Susruta Samhita (16) :

"Time is self-existent (svayambhu) without beginning, without end, and without middle. Even the minutest time is ever-existent. Time is responsible for creation as well as for destruction of all things. Hence life and death are also functions of time (Su 6. 1-2)".

"The fractions of time succeed each other perpetually like the different parts of a revolving wheel. The wheel of time (Kālachakra) revolves eternally with continuous change".

Time is reckoned and measured by the motion of the sun in the heavens (Su 6. 3, 8)".

Finer divisions of time are given in Aryabhatiya [10] and in HCAMI [3]

M. N. Saha's article on the reform of the Indian calendar goes into many details of interest in connection with time measurement [17].

How was time measured? On the larger scale, the year was determined very accurately by Indian astronomers from the apparent motion of the Sun. Since they had no difficulty in dealing with large numbers — thanks to the positional notation of numbers — Indian astronomers estimated one 'Yuga' as 43,20,000 years, the 'Yuga' being a period when all the seven luminous 'planets', Sun, Moon, Mercury, Venus, Mars, Jupiter and Saturn, completed integral numbers of revolutions in the sky. Their estimate has been acknowledged to be remarkable.

On the smallar scale, time was measured by the hour glass — flow of sand or flow of water in the sand clock or water clock. While commenting on Arthaśāstra, A. K. Biswas and S. Biswas write [5b] (p. 53) : "Time was standardized in terms of the solar shadow (of the gnomon) and for the night and a cloudy day by the water clock or nalika ..... A nālikā was defined as the time taken for one ādhaka of water in a jar to flow through a hole of diameter equalling that of a four māsaka weight of gold wire having a length of four aṅgulas."The accuracy was limited because uniformity of flow was hard to ensure and also by the requirement of inversion at regular intervals. Although the wheel of time is visualised, no mechanical contrivance seemed to have existed in ancient India.

In medieval India, sun-dials were in use. A good sun-dial is seen at the Jaipur observatory built by Raja Jai Singh.

IV

Motion : velocity, force

In Vaiseshika-Nyaya [18] and its commentaries, motion outside astronomy was analysed. The notion of instantaneous motion was understood. Examples of rectilinear motion, that is motion in a straight line, were given — an object falling vertically, linear stretching under a pull, etc. When the direction of motion keeps changing, it was called curvilinear motion; rotation and vibration were examples. The importance of rotatory motion, especially of the wheel, was understood. The wheel appears as a divine weapon. However, the notion of acceleration was not introduced and a deeper analysis of rotation was never done.

The causes of motion were discussed and two types were distinguished. In one case, an object moves when another in contact urges it to move by pressure — push or pull or impact. In the other case, motion is caused by action at a distance. In the fall of leaf from a tree due to attraction by the earth — this gravitational attraction of the earth was recognized. Some motions like the upward movement of water vapour on evaporation and movement of iron filings under the influence of a magnet were not properly understood.

Thus rudiments of the notion of force were there, but no quantitative analysis of force and the motion it causes seems to have been attempted. Experimental data were not collected.

Energy

The discovery of the art of making fire is lost in the mist of antiquity. The importance of fire was recognized and in the Vedic period, there appeared a fire god 'Agni'. The Mahabharatam records that fire was made by rubbing two pieces of wood [19]. Otherwise, the Sun was the source of energy directly or indirectly through the generation of biomass.

Chemical energy, for example gunpowder, became available towards the end of the ancient period [6].

Fluid motion

I have mentioned that the principle of buoyancy enunciated by Archimedes was not known in ancient India. In Sanskrit literature descriptions of fluid motion are found : water flowing after the rains or water mixing at the confluence of the big rivers [20]. The two epics tell us that boats plied across the rivers. A naval battle is mentioned by Kalidasa [21]. Historical records exist that boats went out to South East Asia, Ceylon and China from Indian ports [6]. In the Jagannath temple at Puri a stone panel shows one sea-faring boat. Surprisingly, there appears to be no extant literature on the art of navigation. Much is known about the sea trade in the medieval period, but again not much attention has been paid to navigation.

Information about ship-building in India has been collected by A. K. Bag in an interesting article [22].

It is well known that the Ramayana describes a flying machine without adequate attention to the flying mechanism [23]; it had a warrior fighting from behind the clouds [24]. Kalidasa gave a vivid description of the landing of a flying chariot in Abhijnana Sakuntalam[25] and reconstructed the epic flight from Lanka to Ayoydhya [26]. He also watched and wrote of migratory birds flying from the Manasa lakes beyond the Himalayas [27]. Poetic imagination about aerial flights far outshown the capabilities of scientists of ancient India.

V

Modern chemistry starts with roughly one hundred elements of the Periodic Table, which was partly completed in this century and which may even be extended on the heavier side in the next. Compounds of all degrees of complexity can be analysed and synthesised. A molecule is the smallest unit of substance still retaining all the properties of that substance. An element is a pure homogeneous substance which cannot be resolved any further by ordinary chemical methods. An atom is the smallest unit of an element. Atoms of elements combine to form a molecule; a molecule may contain one element and be

monatomic, for example the inert gas Heliun ^4He; a molecule may contain only one element but more atoms, for example, oxygen molecule O_2 is made of two atoms of oxygen. A molecule may contain two or more elements; water for example, contains hydrogen and oxygen with two atoms of the first and one atom of the latter, H_2O. The laws of combination of atoms to form molecules and chemical reactions are still being unravelled through quantum mechanics. Such a treatment of chemistry is very modern; even fifty years ago, when I was a student, chemistry was not taught quite this way. It was a more descriptive subject, and that is the traditional development.

There were two major motive forces in chemistry. First, chemistry dealt with materials useful for practical arts and day-to-day living. It dealt with building materials like wood and stone, dress material, cloth and dyes for colouring them, cooking utensils like pottery, cooking ingredients, salt, handicrafts, metals and alloys, playthings, toys and jewellery. As the well known metallurgist C. S. Smith pointed out, many interesting principles of science — symmetry, for instance — were learnt when making things for beauty and decoration, play and entertainment. Secondly, chemistry had a great deal to do with medicine. Physicians in India tried to find the medicinal properties of every chemical known to them, and in this process, they drew much from botany. There is a well-known tale about Jeevak, who was a physician at the time of Bimbisar and Buddha. As a medical student at Taxila, Jeevak was asked to find plants which had no medicinal value; he found none.

VI

Primordial elements

The reductionist approach in chemistry occurred quite early in ancient India. The details are described in HCAMI. I shall only make some comments on the ideas involved. All matter was made of five 'elements' kshiti, ap, teja, marut and byom (earth, water, fire, air and ether (space)). A somewhat similar idea was prevalent in Greek science [4], so this particular

reductionism was quite old. The word 'element' cannot be used in its modern sense given above; it is better to say five primordial elements for these objects.

I would like to argue that this idea originated in medicinal chemistry. The verb kshi means 'to decay'. So the connotation of 'kshiti' is possibly not covered by the word 'earth', but is better expressed by a word meaning remnant of decay — dust (cf. the phrase 'dust unto dust') or even ashes. A living being is reduced to dust or ashes on death. While alive, it requires water and energy from food. It uses air for respiration. And in its body, it incorporates space like the alimentary canal. A physician would do well by remembering these basic primordial elements, and the idea makes sense. However, pushed too far, it ran into difficulties.

In the ancient and medieval period the Indians came to recognize eight metals (astadhatu) and some alloys of them. These eight metals are : copper, silver, gold, lead, tin, zinc, mercury and iron. The important alloys are bronze (copper and tin), bell metal (copper and tin, but the latter in smaller proportion), and brass (copper and zinc). Their metallurgy was learnt through the work of miners, artisans and craftsmen over hundreds of years. Details are found in HCAMI [3], Sen [1] and in the recent work of Biswas [5]. Why were these metals found first? The noble metals copper, silver and gold occur in the free state. Copper ores were available in India and could be reduced to copper easily. The other metals lead, tin, zinc, and mercury could be obtained from their ores rather easily; their melting points are low, and they could be purified by distillation. Iron in the free state was probably known in meteorites; its extraction from its ore was indeed a remarkable breakthrough. Indians learned the metallurgy of iron rather well : the rustless iron pillar at Delhi and the wootz steel process are well-known achievements.

Among non-metals sulphur, arsenic and antimony were recognized because they were useful in medicine. They also found use for alkali (sodium and potassium hydroxide), alkaline

earth (lime or calcium hydroxide) and various kinds of salts and compounds. Even mineral acid was known quite early.

Towards the end of the ancient period, chemical practices were well developed and driven by the desire for an elixir of life and for transmutation of baser metals into gold. Some people sought immortality or at least eternal youth; if that proved to be too difficult, they sought material comforts by acquiring gold through chemical methods. Scientific methods got mixed with magic and pseudo-religious practices.

On the theoretical side, at one stage, the five primordial elements were given attributes or *gunas* (sattva, rajas, tamas) and also form, colour, smell and other sensory qualities. Again these seemed to emanate from medical practices. The attributes would characterize the psychological make-up or the physiological build of the patient, related to his or her profession, and would be of immense help to the physician. Assigning attributes to metals was bad analogy, perhaps a kind of anthropocentrism. As the knowledge of the inorganic world increased, another stratagem was tried : each primordial element was made into a class. Thus the kshiti or earth-type substances were heavy, hard and inert; the ap or water like substances were easy flowing or viscous liquids; the tejas or fire-like substances were light, luminous and hot; and so on. The ancient Indians had too much data to realize that the five primordial elements were not sufficient, but too little data for pushing further for a new radical classification.

Atomism

The Indian atomic ideas were discussed in Vaiseshika, and in Buddhist and Jain literature; they are summarized by Seal [18] and Sen[1]. I shall make a few comments only. Easy divisibility of matter leads to the concept of 'atom'. If I take an element (I use the word in the modern sense) and keep dividing it, and if the dividing process has to terminate, I arrive at the concept of an atom which cannot be divided any further. Since the world was supposed to be constructed from a few primordial elements,

the ancient Indians arrived at the concept of atoms. Then many questions could be and were raised and discussed throughly. What would be the size of the atoms? How did atoms combine to form a primordial element? When other substances were formed from them, what role did the atoms play?

It was realized that the size of the atom must be small; the linear size was estimated to be 1/348525 of an inch or 7.3×10^{-6}cm. This is not at all a bad estimate. On atomic properties there were debates. Some groups assigned attributes to the atoms and tried to build up compounds by specifying how the attributes combined. The Jain philosophy, however, had proposed attribute-less atoms, which then picked up attributes in the process of combination. From the modern standpoint, one reason for such a debate was that the ancient Indians did not sharply define a molecule in the modern sense. The divisibility argument can be used for a compound too. Take water, for instance; then there will come a stage when only a molecule is left with all the properties intact (one molecule of water). Any further division will destroy the original properties of the compound (water) and will bring out the properties of the constituent elements (hydrogen and oxygen for water). This question of atomic combination leading to new attributes bothered the Indian chemists considerably. Heat involved in chemical reaction was supposed to transform atomic properties somehow; the importance of heat was stressed by Indian chemists. It is interesting to note that the combinations of atoms in groups of two, three, four and so on are not very different from what was discussed by the proponents of modern atomic theory.

Chemical energy : Gunpowder

The knowledge of gunpowder came to India from China directly or through Tibet probably towards the end of the ancient period. It was regarded as a curiosity, and used in firework displays, but not much effectively in war. It is recorded that [6] (p.387) 'a machine discharging balls by force of gunpowder [was] used, though not with much effect as early as the reign of Iltutmish' (1210-1229). The Mughal invader Babur brought and

used guns effectively (1525-30). Since that time brass and iron guns were made in India extensively; many specimens are preserved in various parts of India. Nevertheless the Indian gunnery proved to be inferior to the European at the end of the medieval period. History records that many Indian kings employed European adventurers and mercenaries — Portuguese, French and English — in handling artillery.

VII

The quality of Indian contribution to chemistry is superior to that to physics. Chemical experimentation was extensive; experiments in physics never gained popularity and a combination of experimental skill and theoretical ability did not appear. Some people think that the quality of science declined when the debate between the traditionalists and the break-away groups like the Buddhists and the Jains disappeared; others believe that the thinkers belonged to the upper caste and the doers to the lower caste and the two did not come together. The last argument is difficult to accept because chemical and medical experimentation was done without much hindrance from the casteist difference. One should not ignore that great individuals do matter in a radical departure from a set pattern of thinking, and somehow such a great personality combining theoretical and experimental ability in physics did not appear in India.

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II - 3

BIOLOGICAL SCIENCES IN ANCIENT INDIA

SRABANI SEN AND R. L. BRAHMACHARY

In several parts of the world, including India and neighbouring regions, between 8,000 - 10,000 years ago our ancestors worked out a scientific revolution of the highest order—domestication of grass into rice, wheat, barley etc. Those men and women — and woman the traditional forager might have played a greater role in this feat than did man the traditional hunter — altered the course of history, for, cultivation together with the use of fire paved the way to what is termed as civilization of stable societies and the arts and sciences developed therein.

Agriculture and domestication of animals which seems to have closely followed it are a stupendous achievement of science. To quote Levi-Strauss (Maybury-Lewis, 1992), the transformation of a wild grass or weed "into a cultivated plant, a wild beast into a domesticated animal, to produce in either of these nutritious or technologically useful properties which were originally completely absent or could only be guessed at .... there is no doubt that all these achievements required a genuinely scientific attitude, sustained and watchful interest and a desire for knowledge for its own sake. For, only a small proportion of observations and experiments could have yielded practical and immediately useful results".

In this sense the conversion of grass into rice and domestication of the elephant are the highest examples of both pure and applied science of ancient people in India, possibly the Proto-Australoid races who developed agriculture and animal husbandry some 5-6,000 BC or 7-8,000 BP (Walker, 1968). Rice has been unearthed in Lankaransar (Singh, 1974), Mehergarh and Mahagarh (Biswas, 1996) about 6,000 BP. The origin of wild rice was somewhere in the coast of Bay of Bengal, possibly in Andhra, Orissa or Bengal and at least 1,000,000 varieties had been developed by the ancient Indians and many of these were endowed with unique properties such as salt-resistant, nutritious, fragrant, flood-resistant strains which may well be the envy of modern genetic engineers (Brahmachary, 1996). Unfortunately, at present perhaps no more than 2000 varieties are extant.

The proto-australoid " scientists" also left their mark in the Indian agricultural scenario in the form of brinjal, pumpkin, banana, betel vine, turmeric (with its use in religious rites); moreover we owe them a legacy in that the Sanskrit terms for rice, straw, hoe, yoke, plough, sickle etc. seem to have been derived from Austric words (Walker, 1968).

It is however difficult to ascertain the exact extent to which the different ethnic or cultural groups such as the Austric, Kolarian or Aryan exchanged and adopted scientific knowledge from one another. The Kolarian who probably antedated the Austric, might have had some important ideas or technology to offer.

Domestication of animals was another landmark of scientific achievement and in India, in particular, we see the flowering of this science that succeeded in taming so many creatures, from wild fowl to wild elephant. According to one school of thought (Hilzheimer, 1920, see Marshall, 1931) *Haustierkultur* (culture of domesticaiton of animals) must have been antecedent to agricultural activities; cattle or horse used for ploughing induced a deep seated change in agriculture which initially was possibly based on manual broadcasting of seed. As against this one may state that a purely hunting-gathering society could not possibly

attract wild ruminants (the ancestors of cattle, goat etc.) to the dwellings of the nomadic or seminomadic people and so a close contact with these animals, the first step towards domestication, would not be possible (Mucke, 1898, see Marshall). We may counter this argument by another. Many tribals in India know or knew the art of attracting such ruminants with the help of salt. It is possible that hunters noticed the salt-hunger of these animals as evident at natural salt-licks and thus developed the artifice of bringing the creatures close to tents, huts, or caves. This would facilitate hunting and sometimes the confused and orphaned young ones might tarry and be captured. While some would be immediately slain, others might have been reared, perhaps by the womenfolk and the long way to domestication would be in sight. Be that as it may, the ancient Indians tamed a number of species such as some breeds of dogs derived from the Indian Pariah dog and/or Indian wolf, the famous zebu cattle and the Bos primigenius with horns pointed frontally (both animals are clearly depicted in the Mohenjo-daro and Harappan seals), the water buffalo (which may have originated in China), the goyal and mithan, domestic fowl and the elephant (Zeuner, 1963). In Mohenjo-daro and Harappa the figurines of fowl seem to be fighting cocks, for sport. In Yajur and Atharva Veda fowl is mentioned, though not in Rig Veda (Zeuner, 1963).

The most spectacular *tour de force* in this field must have been harnessing the elephant. Although unlike the dog or horse, various breeds differing in form and behaviour have not been developed in the elephant, over thousands of years they have been trained to execute adroitly the process of collecting, arranging and transporting logs and respond to various commands of *mahouts*. The depictions of elephants in Indus valley seals mix up the African and Indian elephants and so the domestic Indian elephant could not have been very common in that region (Mackay, 1935), perhaps other people in Southern and Eastern India (e.g. Palakapya) tamed the elephant.

In all parts of the world primitive men discovered medicinal properties of plants. In the Vedic and post Vedic literature such

as Caraka and Susruta Samhita we find references to 700-1000 medicinal plants. We could also predict that more would be revealed in the knowledge bank of the Indian tribal people and this has indeed been borne out by a recent ethnobotanic survey (Pusphangadan, 1994). Even now various tribals know the use of 7500 medicinal plants, 3900 as food items and 525 plants as the source of fibres, ropes etc. To take another example of the knowledge of plants as mastered by people living close to Nature—the Todas of Nilgiri can predict the end of the monsoons even when pouring rain is descending from the vaults of the heavens, for, at the very last phase of the rainy season the white, fragrant flowers appear in the *Michaelia nilagirica* plant and the wild Balsam tree blooms just at the onset of the post monsoon period (Chhabra, 1999). Other flowers indicate different seasons and the time of the day.

Only a small part of this age old tribal knowledge is likely to have been marshalled and codified in the later civilized era but the scholarly people who did the work of documentation were likely to have been less familiar with Nature and the civilized or ruling class might have created an artificial barrier between themselves and the subservient or sylvan races. For example, the term " Brihimatya" meaning the cultivators of Brihi (rice) was used by the dominant, so calledAryan barley eaters to indicate a rather ignoble profession (Monnier-Williams, 1899).

The Asokan edicts proclaim a Buddhistic philosophy as well as ecological wisdom, part of which is likely to have orignated in earlier tribal culture. These edicts recommend conservation of plants, including medicinal plants, on which great emphasis was laid, and various animals. A list of such animals was furnished. A surprising aspect of Asokan edicts is enjoining conservation of bats and flying foxes (fruit bat) and termites or white ants which do not enjoy any religious sanctity. Mukhopadhyay and Brahmachary (1998) have discussed this aspect. Till today many rural people think that fruit bats play a role in the dispersal of fruit trees and evidence for a sort of reverence paid to these animals

is also to be noticed in certain quarters. Today ecologists evince a consensus of opinion namely that fruit bats contribute very substantially to the propagation (seed dispersal) of many tropical tree species. A spectacular case is that of ié ié vine in Samoa islands. This very important plant, economically and culturally, vanished as the fruit bat were exterminated (Balick and Cox, 1996). Likewise, white ants, though a pest or at least an unmitigated nuisance in the house, has a significant role to play in the ecology of certain regions (Mukhopadhyay and Brahmachary, 1998). The people of Vedic ages were members of a pastoral society and hence interested in animal life. There was a superb tradition of making careful observations and accurate recording of plants and animals. As a result we have references to some 740 plants and over 250 animals in our ancient literature like Rigveda, Artharvaveda, Taittiriya Samhita, and as already mentioned, Susruta Samhita, Caraka Samhita, etc.

Classification of Animals

The Rg-veda does not furnish any indication of classification of animals other than the division of common mammals into two groups, viz., the domestic forms —gramya and the wild animals which live in forest — aranya. The first attempt to classify animals in some rational way is found in Chandogya Upanisad (VI.3.1), where classification was based on their mode of origin and development into the following three main groups.

1) jivaja (viviparous)

2) andaja (oviparous)

3) udbhijja (of vegetal origin or arising, like vegetables from the earth)

All mammals belong to the first group and all birds, reptiles, insects and worms to the second group. The third group comprises minute animal organisms. It is interesting that all animals that were small and apparently caused some damage or discomfort, were thought to arise spontaneously, out of the earth. This is totally unscientific but even in Europe it was only in the

eighteenth and nineteenth century that the theory of spontaneous generation was finally discarded by Redi, Spallanzani and Pasteur.

Post Vedic Indians acquired a more comprehensive and detailed knowledge of animals. Susruta Samhita (600 B.C.) classified all substances into two main divisions: sthavara (immobile) and jangama (mobile). Plants belong to the first category. Plants were again subdivided into four classes :- Vanaspati (that yield fruits, without blossoms), Vrksa (endowed with both flowers and fruits), Virudha (shrubs and creepers) and Osadhi (which die with ripening of fruits).

Susruta gave a more or less detailed account of different parts of plant body : ankura (sprout), mula (root), kanda (bulb), sara (hard core inside the trunk), kririna (laticiferous tissues), tvak or niralekhana (bark), patra (leaf), patrasevani (large central vein), puspamukula (bud), patrakesara (seed organ of flower which has a fragrance), puspa (flower), phala (fruit), asthi (stone or seed inside fruit), kesara (fibre of the fruit), majja (marrow of the fruit), mamsa (pulp of the fruit), tvak (rind of the fruit). These are very similar to the epicarp (rind), mesocarp (pulp), etc. of modern botanists. Susruta attempted two different clasifications of plants. In one of these the plants are divided into thirty-five Vargas (group) based on therapeutic value. In each varga the plants are arranged in a highest to lowest order in terms of intensity of their therapeutic values. Susruta has also classified the plants according to their dietetic nature.

The most elaborate classification of plants was by Parasara (1st century B.C. to 1st century A.D.) who based it largely on morphological considerations. But such a classification was not improved subsequently. Susruta Samhita (600 B.C.) and Caraka Samhita (100 B.C.) classified animals according to their food habits and habitats into two main divisions —Anupa and Jangala. Anupa was again subdivided into five groups as follows :

Kulacara - herbivorous quadrupeds that frequent the banks of river and ponds, e.g., elephant, rhinoceros, buffalo.

Plavas- amphibious birds, e.g. goose, duck, crane.

Kosasthas - molluscs such as pearl oyster and snail.

Padins- aquatic animals with pedal appendages, e.g. tortoise, turtle, crocodile, crab.

Matsya- Fresh water and sea fishes.

The jangala group was subdivided into eight sub groups.

Janghala - wild, herbivorous quadrupeds that are strong-legged and quick footed, e.g., deer and antelope.

Viskiras - All birds that scatter their foods while eating.

Pratudas - Birds that tear or pierce their food with their beaks.

Guhasaya - Carnivorous quadrupeds living in natural caves, e.g. lion, tiger, wolf, panther, cat, etc.

Parnamrga - arboreal animals, e.g., ape, squirrel as well as some species of reptiles and carnivores.

Bilesaya - animals that live in holes or burrows, e.g., some species of rodents, insectivora and reptiles.[4]

Gramya - domesticated quadrupeds, e.g. mule, cow, goat, sheep, horse.

The above way/ mode of classification of animals was not fully scientific from the modern point of view but the attempt taken by these post Vedic people reveals that there was an interest in animal life and animal behaviour was keenly observed.

Susruta Samhita (600 B.C.) (see later) records some meticulous observations on snakes and leeches. Snakes were divided into five groups. Of these, four— darvikara, mandalin, ajimat and vaikaranja — are venomous. The other group comprises of non-venomous types. A long list of groups and subgroups of venomous snakes with their external features was

described in detail in Susruta Samhita (v.4, 2-17). Susruta took great care and interest in leeches as this animal was extensively used by him in blood letting and even removing blood clots in post-operative cases. It should be noted that U.S. medical scientists recently attempted to use leeches in post operative surgery to remove blood clots. Leeches were divided into twelve varieties of which six were poisonous and the other six, non-poisonous. The non-poisonous varieties were used in surgery during that period. Even the diseases of leech were carefully studied. These observations, experiments and applications of leeches in surgery during Susruta's time can be concluded as rational and most scientific; this science developed along the same line of thought as that of western modern science.

Patanjali - Mahabhasya (c. 150 B.C.) speaks of Ksudrajantu (small animals) and defined them variously as :

1. animals without bones
2. animals without blood of their own
3. animals so minute in size as to be more than a thousand in number in a palmful
4. animals not easily crushed

A more comprehensive classification of animals is found in the ancient Jaina work "Tattvarthadhigama sutra" of Umasvati (c.40 A.D.). This classification is based on the increasing number of senses possessed by the animals —an evolutionary trend. Umasvati's classification, whatever might be its defects from the modern point of view, was a bold effort and excelled contemporary attempts made in the western world, dominated by Aristotle's idea and contribution. In fact, in their attempts to introduce a system of classification, these ancient Indians appear to have devoted a more meticulous care to bring animals within the boundary of certain rational groups. They achieved a larger measure of success than the Chinese or the Egyptian. The Egyptians do not seem to have undertaken any classification of

animals, though they were familiar with many and we notice many pictures of crocodiles, hippopotamus, mongoose,swamp birds, etc. The extant records of the Chinese (Needham, 1992) also suggest that they were less interested in animals than in plants and apparently did not try to classify the animals.

Veterinary Sciences

Some ancient treatises of uncertain dates like the Hastyayurveda or Gajayurveda (i.e., the veterinary science of the elephant) by Palakapya, Asvayurveda (equine veterinary science), Asvacikitsa (treatment of horse) and Asvasastra (knowledge of horse) by Nakula deal with the treatment of diseases of elephant and horse. Asvacikitsa of Salihotra was concerned with the anatomy, life, characteristics and training of horses. Diseases of horses such as " cough, indigestion, diarrhoea, skin diseases, apoplexy, madness, etc. and surgical operations for treatments of malformation" have been described in these works; likewise topics such as " anatomy, physiology, habits, mating habits, seasonal changes, stabling, food, sterility and madness of elephants" were also treated (R.C. Mazumdar, 1971). Bandopadhayaya & Brahmachary (1999) pointed out a number of factually sound data on certain physiological and behavioural aspects of elephants in Gajasastra. A remarkable description is that the oestrous or pro-oestrous elephant flings up its tail, a fact discovered as late as in 1972 by Krishnan (1972). Today this is known as scent-flagging. These works on the elephant and horse are impressive examples of vet sciences.

Fisheries Sciences

King Someswara, the son of king Vikramaditya VI, who composed a book, " Manosollasa" in A.D. 1127 was the first to record the common sport fishes of India. But a more important example, that of ecological adaptation of fishes to their respective habitats, has been noticed by Susruta. Hora (1935) describes this thus : " The river fish are bulky in the middle because they move with their head and tail, the lake and tank fish are similar ....

(but have) a relatively small head, the spring and pool fish..... are extremely deep behind the head, the fishes of torrents .... (possess) a greatly flattened body on account of .... crawling with the chest and a relatively reduced anterior part of the body. In 1930 Hora studied fish morphology in torrential streams and afterwards he noticed the striking similarity of his findings to Susruta's description (Hora, 1935). Tamil Sangam literature (400-800 A.D.) of South India referred to a large variety of mammals and birds and a few species of insects, reptiles and fishes.

Susruta, A Monumental Achievement

Susruta Samhita is a fascinating medical compendium. In no other context can it be said more emphatically that the very same trend of western science had developed in India more than two thousand years ago. A robust self confidence based on the scientific method seemed to have rivalled and overcome the obscurantistic approach and reliance on god or fear of evil spirits. It is a pity that such a powerful stream of science altogether dried out instead of gathering force with the passage of time. In the final form in which we have inherited this Samhita, strange superstitions seem to be mixed up with a clear thread of unalloyed science based on reasoning and experimentation running through its fabric. It is not difficult to separate the grain from the chaff (Brahmachary, 1997).

Fairly reliable English translations of Susruta are available (Kunjalal Bhisagratna, 1907-1917; Ray, Gupta and Roy, 1980; Satya Prakash, 1965) so that we can appreciate the astonishing development of surgical science in ancient India. As in all other similar sources, such as Caraka Samhita, Surya Siddhanta, the origin of the science is lost but both Caraka and Susruta Samhita seem to have flourished during the early Buddhistic period though the roots evidently go back to earlier era.

The most important achievements of Susruta are the following:

He is acknowledged to be the father of plastic surgery. During

the reign of Tipu Sultan, an Indian personnel of British Army was caught by Tipu's men and had his nose and ears amputated. He sought out an Indian practitioner in whose family Susruta's surgical methods were still known— thanks to the continuity of knowledge between master and disciple. The operation was successful and the story was published in a London magazine and fired the imagnation of a British Surgeon who first saw success in 1816.

Another spectacular case described in the Samhita is joining severed intestine, perhaps as a result of a blow from a spear or sword. The intestine was taken out by enlarging the abdominal wound and the two severed ends joined with the help of ant heads as staples. (The surgeons had in their possession several types of sewing needles but for this purpose the ant heads were deemed to be the best). The use of ants for such a purpose has been noticed in other continents as well.

Again, more than 50 operations on the eye were described. For these and other surgical work a hundred or so instruments, some of them very fine, were devised.

The preparatory process (Purba Karma) before undertaking the surgery proper, includes among other things, the meticulous care for anaesthesia and sterilization. The former was achieved with the help of intoxicating wine (Arista or wine for medicinal purposes) mixed with other medicine from vegetable sources. Sterilization was carried out with the help of flame and the instruments were generally kept in a scrupulously clean state. This, thus, is equivalent to Lister and Pasteur's time in the late nineteenth centrury. Likewise, the concept that some diseases like diarrhoea and dysentery are water-borne is also clearly stated in Susruta. It seems the Susruta school correlated the incidence of such diseases with indulgence in aquatic sports in ponds and tanks where the swimmers gulped in polluted water.

The patients suffering from these diseases were recommended to drink boiled water and milk and some medicine from barks of plants would be mixed in it.

That these diseases can be water borne is a concept we notice in Europe in the second half of the nineteenth century. During the outbreak of cholera in London at that time an eagle eyed doctor noticed that people using a water source that was contaminated with the sewer were prone to the disease while another uncontaminated one was safe. This was before Koch's attempts to understand the microbial basis of cholera. He came to Calcutta to study cholera. Interestingly more than two thousand years ago Indians knew that the disease was water borne.

How the ingenious technique of boiling water or sterilising the surgical instruments first arose is lost in the hoary antiquities, but Brahmachary (1997) speculates that the mystic aspect of fire, fire as a God and as a purifier, might have something to do with it; perhaps merely as a ritual the surgical instruments used to be cleansed with fire and then astute observers noticed that unsterilized or less sterilized scalpels were more dangerous.

We thus see that in this field of applied science (medical science) the highest development humanly possible at that time did take place in India. On the other hand, we do not find the Aristotelian approach, the study of lowly forms of life *per se*. While even human embryology was studied within the perspective of medical science, nobody broke open birds' eggs at different stages, as did Aristotle in order to shed light on the fundamental problem of the growth of a bird from an egg. Nor is there any description by a scholar of the life cycle of a frog from egg to tadpole to adult.

Atreya, in his arguments on soul (human and animal) says "the argument of parental souls being reborn runs into a difficulty in case of andaja and swedaja, for these are not born of parents" (Caraka Samhita). It is surprising that an erudite scholar of his rank had no concept of parental origin of eggs. Even children in rural areas observe that insects, not to talk of birds, do lay eggs.

In conclusion, then, we note that applied biology in the form of medical and veterinary sciences attained a peak in India more than two thousand years ago but biology as a pure science was

less developed. But this was probably so in other ancient civilizations as well. Aristotle was an exception.

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II - 4

THE RISE AND FALL OF ISLAMIC AND CHINESE SCIENCE

ASHISH LAHIRI

Before entering the subject proper, I have the following observations to make.

1. Science is one human activity where *homo sapiens* as a whole directly makes an attempt to come to terms with nature. Science is thus one — or 'Ecumenical', if you prefer to use Joseph Needham's elegant phrase. Therefore. terms like 'Western', 'Islamic' or 'Chinese' Science are misnomers. If one still uses them, that is simply because of convenience. It would have been proper to use titles like 'Ecumenical Science under the Islamic Banner', or 'Ecumenical Science: Its Chinese Chapter'. Obviously, they would have been too cumbersome as titles. Hence I have stuck to the traditional labels, although I mean exactly what these cumbersome specimens would suggest.

2. Compared to the steady, vast and enormous growth of Chinese science in time, the rise of Islamic science can well be called meteoric. It had come and gone within a span of four hundred years. If its effect on modern science has been much more direct and acknowledged, that is because of its direct contribution to the European Renaissance. Thus, when it disappeared from its mother cultures, it was sensible

enough to hand over its assets, lock, stock and barrel to Europe, thereby rescuing the latter from the quagmire into which it had fallen during the Dark Ages under Christianity. In the case of China the thing was entirely different. There, the great tradition virtually withered away, without leaving any inheritor. Moreover, while Islamic science was in essence a continuation of Greek science, Chinese science had its own traditions which made assimilation difficult. Not that it was esoteric or insulative, but an intellectual tete-a-tete with the West was absent. The result was, the West was almost totally ignorant about the great traditions of Chinese science, although they had been using many of the Chinese contributions to technology for a pretty long time.

It is only over the past fifty years or so that this enormous treasure has caught Western attention, largely due to the efforts of Joseph Needham and his collaborators. For us, too, the comparatively recent exposure to the history of Chinese science has been an awesome revelation.

Consequently, our perceptions of Chinese and Islamic sciences have been very different. In this short discussion, I have not attempted to show how there is an essential link between the two. I have treated Chinese science and Islamic science as two different entities, without trying to make comparisons or to trace relations, knowing fully well that this is patently inadequate.

3. Finally, I must warn my audience that this paper is a mere compilation, translation and juxtaposition of texts almost bodily lifted from standard books on history and history of science. There is nothing in it which I can claim to be original.

I

The Rise and Fall of Islamic Science

The decline of the classical culture and the rise of Christianity conspired, so to say, to seal the book of science in the West. Late

classical culture was limited both socially and geographically. Socially it had become an almost exclusive preserve of the upper classes. Intellectual snobbery prevented the learned sections of the society from gaining access to the enormous wealth of practical knowledge that was locked in the traditions of almost illiterate craftsmen. Geographically, classical culture was limited to the countries of the Mediterranean and the near East. Contact with the techniques and ideas of India and China was virtually nil. With the breakdown of the Roman Empire the way was open to much wider exchanges and influence.

On the theoretical front, the triumph of Christianity effectively meant that all intellectual life, including science, was inevitably expressed in terms of Christian dogma. Between the fourth and the seventh centuries the history of thought over the area of the vanishing Roman empire is the history of Christian thought.

In this essentially stifling scenario, Islam brought in a breath of fresh air. Early Islam had a far less cramping effect on human thought than that of Christianity. Between 622 and 632, Mohammed swept away the old Arab tribal gods and replaced them by one God. Within five years of his death in 632, Islamic armies had decisively defeated both the Roman and the Persian armies. By the eighth century they extended their conquests from Central Asia to Spain. The Roman dominions in Africa and Asia, with the exception of Asia Minor, were in their hands, stretching right over Central Asia into India. Thus, a vast area now had a common culture, a common religion, and a common literary language. Religion and the pilgrimage ensured free passage from Morocco to China of scholars and poets.

The immediate result was a great stimulus to culture and science. Quite understandably, Islamic science had a marked comprehensive tendency. The unity of science was ensured by the tradition of encyclopedism. Under the influence of this many Islamic scientists composed comprehensive treatises like the *Compendium of Astronomy* by al-Fargani (d.c. 850) and the great medical collections— like the *Howi, Liber Continens* of Rhazes (865-925), the *Canon* of Avicenna and the *Colliget* of Averroes.

This comprehensive tendency was all the more valuable, because its wider inclusion of the knowledge of other countries gave Islamic science a distinct advantage over that of the classical times. The Arabs were able to make use of the Mesopotamian astronomical and mathematical tradition. They consciously used the ancient knowledge of India, and to a lesser extent, of China. This was most conspicuous in Islamic Mathematics, Astronomy, Geography, Medicine, Optics and Chemistry. The interaction with India is of particular interest to us. During the reign of the Abbasid Caliphs the Baitul-Hikma (The House of Wisdom) was established. Caliph al-Mamun actually founded a bureau of translation (Dar el Hikma), where great scholars produced Arabic texts of Aristotle and Ptolemy on the one hand, and of Indian scientific texts on astronomy, mathematics and medicine on the other. Unfortunately, the Indian books were not further translated into Latin, and were thus lost to the West.

In Mathematics they borrowed heavily from the revolutionary Hindu system of numbers. This technical device had almost the same effect on arithmetic as the discovery of the alphabet on writing. Al-Khwarizmi learnt Sanskrit and wrote on the works of a series of Indian mathematicians on the means of dealing with unknown quantities, and thus developed Algebra. Al-Beruni, during his stay in India in the 11th century studied Indian sciences. He has given a detailed account of the Indian numerals in his books. In the earliest available Arabic book on Indian arithmetic, named 'Book on Principles of Hindu Computations', al-Uqlidisi offered some interesting suggestions in 952/953 A.D. After dealing with Hindu numerals and place value notations, he suggests :

1. The Indian schemes be modified, whereby the abacus can be dispensed with, and pen and ink used instead.
2. Greek letters might replace the nine Indian numerals.
3. The Indian numerals with super-imposed dots might form a new Arabic alphabet.

These suggestions clearly reflect the combined influence of Greek and Indian scientific ideas on them. Arab Trigonometry too was much influenced by Indian ideas.

In Astronomy, they mostly carried on the Greek traditions, adding little to theory. In this field too, they were greatly influenced by Indian science. Their interest in scientific astronomy was aroused by the knowledge that Indians possessed a much better system of preparing reliable and accurate calendars. It is reported that an Indian astronomer visited al-Mansur's court, bringing with him tables of the equations of planets according to mean motions, with observations relative to both solar and lunar eclipses and the ascension of signs. Al-Mansur ordered the translation of Brahmagupta's *Brahmasphutasiddhanta* and *Khandakandadhyaka* into Arabic.

Geography was for them a special branch of astronomy. Here again, though they made little theoretical advance, on the practical side they virtually laid the foundations of the modern geography of Asia and North Africa. This was the result of the wider range of the Islamic world and the decentralization of their culture.

Islamic Medicine was a direct continuation of Greek medicine. However, by virtue of their wider geographical spread, they could add a knowledge of new diseases and drugs. The prestige of doctors was very high, as were their intellectual standards. The fact that nearly all Islamic scholars were doctors had an important influence on their scientific and philosophical outlook.

Optics was one branch of science where they excelled. The surgical treatment of eye conditions led to a renewed interest in the structure of the eye. This in turn led to a study of the passage of light through transparent bodies, and hence to the foundation of modern optics. The lens of the eye was to point the way to the use of crystal or glass lenses for magnification or reading. The Optical Thesaurus of Ibn al-Haitham (Alhazen, *c.* 1038) was the first serious scientific treatment of the subject. If they had done nothing else, the Islamic doctors in founding optics would have made a decisive contribution to science.

However, their greatest contribution to science was in Chemistry. Geber was its legendary founder. Their success in this field was largely due to the fact that Islamic doctors, perfumers

and metallurgists could escape, to a great extent, the class prejudices which kept the Greek away from the manual arts. Arab chemists drew heavily on Egyptian, Babylonian and Greek traditions, and to a lesser extent on the extensive chemical knowledge of the Indians and the Chinese. Originally Arabic alchemy was not so much a method of preparing gold but of the elixir of life. They vastly improved distillation techniques and used them to produce perfumes on a large scale. They might also have taken the next crucial step and distilled alcohol, had it not been for the Koranic prohibition of wine. Thanks to them, it was possible for the first time to approach chemical transformation rationally.

To sum up, in its central themes Islamic science is a continuation of Greek science. The Islamic scientists rescued Greek science from its decadent state under the late Roman Empire. However, with all its glory, it must be said that at no point does Islamic science attain the great heights of the Ionic Nature philosophers or equal the geometric imagination of the Alexandrian school. Nevertheless, by drawing on non-Hellenic sources like Persia, India and China, they could extend the narrow base of Greek mathematical, astronomical and medical science, could initiate the techniques of algebra and trigonometry, and lay the foundations of optics. Their crucial contribution was in chemistry or alchemy. Here they transformed old theories and added new experiments to create a new discipline and tradition of science. This tradition was often qualitative and mystical in character, but for that very reason it was to be an invaluable counterweight to the over-rational and mathematical-astronomical-medical tradition of the Greeks.

It is difficult to estimate the value of the actual contribution of Islamic science to the general pool of learning. Certainly the learning of the Greeks was brought to life again and not merely transmitted without change. In fact it was subjected to a process similar to that undergone by the learning of the ancient East in the hands of the Greeks, though in this case the affiliation was far more direct and acknowledged. Because the Islamic scholars

had no emotional identification with the old legends of the Greeks, they approached Greek learning with a more detached attitude than the Greeks themselves. On reading Islamic scientific works one is struck by a rationality of treatment that we associate with modern science. On the other hand the Muslims were equally, if not more, attracted to the mystical aspects of late classical philosophy, particularly neoplatonism, which they at first were unable to distinguish from Aristotle, owing to the incorporation in his works of such forgeries as the *Theology of Aristotle* and *The Secret of Secrets*. Sufism represents a neoplatonist alchemical tradition of the Arabs. Another misfortune that was to dog Islamic science was the exaggerated respect that was paid to the works of the Greeks, and particularly to Plato and Aristotle. The fusion of the number magic of Plato with the 'quality hierarchy' of Aristotle was a multiplication of nonsense from which Islamic science was never able to free itself. It is, however, interesting to notice that, though the two great mystifications of early science, astrology and alchemy, were pursued by the Arabs, the greatest figures of Islamic science such as al-Kindi, Rhazes, and Avicenna explicitly repudiated the extravagant claims of these pseudo-sciences.

The social position of the scientists in early Islamic culture was not essentially different from what it had been in late classical times. With the coming of the Abbasid dynasty (750) there was a short period between 754 and 861 under the Caliphs — al-Mansur, Haroun-al-Raschid, al-Mamun, and even under the devout al-Mutawakhil — when science was encouraged on a scale unequalled since the early days of Alexandria. The Omayyad Caliphs at Cordoba (A.D. 928-1031) and the petty Emirs who succeeded them in Spain and Morocco, ambitious princes such as Saladin, Mahmud of Ghazni, and Ulugh Beg of Samarkand prided themselves on encouraging science. In addition, rich merchants and officials, such as the Persian family of the Barmecides (*c.* 750-803) and the three brothers Musa (*c.* 850), supported scientists and some were themselves interested in science. This secular and commercial background of Islamic science marked it off sharply from that of medieval Christendom,

which was almost exclusively clerical. It resembled far more that of the Renaissance. It was this courtly and wealthy patronage that enabled the doctors and astronomers of Islam to carry out their experiments and make their observations. For a time it also protected them from the active disapproval of religious bigots who suspected that all this philosophy would shake the beliefs of the faithful.

This association of science with kings, wealthy merchants, and nobles was immediately the source of its strength and ultimately of its weakness. Science became, as time went on, completely cut off from the people, who suspected that the learned advisers of the great were up to no good, and this made them an easy prey to religious fanaticism. As long as the cities and trade flourished there was a sufficiently large, cultivated middle class interested in science to ensure discussion and progress. As this broke down, the scientists became more and more wandering scholars, dependent on the varying fortunes of local dynasties. Even the greatest of them, Ibn Sina (Avicenna), was never granted any security. He served sultans in Persia and Central Asia, sometimes as doctor, sometimes as vizier. At Hamadan he escaped by a feigned illness from mutineers who were demanding his head. Ibn Khaldun (1332-1406), the last of the great Muslim thinkers, was a refugee from Seville forced to take service wherever he could find it. In his time he was to negotiate with Pedro the Cruel in Spain and Tamerlane in Syria, both of whom offered to employ him.

Clash with Orthodoxy

The scientists of Islam on the whole accepted and codified the late classical pattern of the sciences. They had little ambition to improve it and none to revolutionize it. As al-Biruni (973-1048) put it, 'We ought to confine ourselves to what the ancients have dealt with and to perfect what can be perfected.' Though individuals might specialize, science formed a unity cemented by philosophy. It comprised the twin disciplines of astronomy and medicine, united by a more of less admitted astrology which furnished the link between the outer big world of the heavens —

the macrocosm — and the inner small world of man — microcosm. Philosophy as such was suspect — it was difficult to reconcile it with the Koran. Pious Muslim scholars certainly attempted to do so but this was frowned upon by the orthodox. This inevitably forced the doctrine of two truths—a higher spiritual and a lower rational truth. The ultimate failure to associate science with the enduring features of Muslim religion was probably a major reason for its withering away in the later centuries of Islam, which became culturally and intellectually static. This incompatibility of science with religious orthodoxy is best exemplified by the conflict between al-Ghazzali's (1058-1111) standpoint and that of Ibn Rushd (1129-98). Ibn Rushd argued that matter was immutable and creationism was false. The whole universe is driven by some integrated principles and laws. Among those principles one is Active Intelligence. This intelligence continually finds expression in man's collective consciousness, and it is this Intelligence which is truly eternal. Obviously, this theory did not go well with the precepts of Islam. In order to arrive at a conciliation between Aristotle and Islam, Ibn Rushd developed the brilliant argument that God and his Creation were both co-eternal. True, God has created time and the universe, but he has created these for whole eternity. God himself is without cause, self-emergent; similarly, his creations too do not have any definite cause or time. Thus, he opined, there was no fundamental contradiction between the idea of immutability of matter and the universe, as proposed by Aristotle on the one hand, and Islamic Creation Theory on the other.

This secular rationalism was furiously opposed by the disciples of al-Ghazzali, who in effect preached a kind of Mayavad. In his book *The Destruction of the Philosophers,* al-Ghazzali had warned of the futility of all attempts at reconciling Islam with rationalism. It was in order to expose the philosophical hollowness of this dogmatism that Ibn Rushd wrote a spirited answer in his *Destruction of the Destruction.* But he failed. Al-Ghazzali's blind and dogmatist followers won the day. At their behest the Caliph al-Mansur banished Ibn Rushd from Cordoba and a bon fire was made of his philosophical works.

However, during the most flourishing period of Islamic science, in the ninth, tenth, and eleventh centuries, these considerations did not yet weigh heavily. Indeed one may suspect that religion was taken for granted by some of the greatest scientists, and not allowed to interfere with the pursuit of secular knowledge.

The decay of Islamic Science

After the eleventh century, the best days of Islamic science were over. True, there were still brilliant individual scientists coming up. One of the greatest, Averroes, dates from the twelfth century, and Ibn Khaldun comes as late as the fourteenth. But the point is, they were no longer part of a widely based and living movement. The failure of Islamic science was essentially an aspect of the general political and economic decay of Islam in its original form. The Islamic Empire was unable to maintain the organization necessary to control an extensive State. Already by the tenth century it had begun to break up internally. By the time of the Crusades they had developed into a local feudalism which was inferior militarily, and culturally no longer markedly superior to that of the West.

Its breakdown was accelerated by the arrival of new waves of barbarians from the Steppe lands, The irrigation agriculture of Mesopotamia was largely ruined by a combination of native misrule and Mongol incursions which prevented the maintenance of the canals. However, barbaric invasion alone was not responsible for the decline of Islamic civilization, particularly science. This is borne out by two facts. First, the civilization of Egypt also broke down, where the Mongols never penetrated. Second, despite similar barbaric incursions, China and India continued to flourish. Thus, there were other deeper internal factors involved in the decline of Islamic science and civilization — which we have hinted at above.

The equilibrium reached in the Mongol and Turkish States that succeeded the original Arab empires was essentially hostile to science. Thus science stayed basically frozen at the stage it had reached in the eleventh century. The Mullahs and Maulavis

actively discouraged any study of science and philosophy that was not sanctioned by their scripture. Gradually the Islamic tradition of secular and rationalistic thought died down. What remained was a sterile theocratic obscurantism.

However, the great Islamic contribution to science was not lost to mankind. Its whole apparatus — data, experiments, theories and methods — were handed on to the new, growing science of feudal Christendom. Indeed, if one were to write a comprehensive history of Ecumenical Science, logically one should treat the whole period from the seventh to the fourteenth century as one single chapter of intellectual advance comprising Syrian, Persian, Indian, Arabic and Latin influences.

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ISLAMIC SCIENCE : IMPORTANT EVENTS

600 - 800 A.D.	Rise of *Mohammad* — *Geber*, legendary founder of Islamic Chemistry —Translations from Sanskrit, Syriac and Greek into Arabic
800 - 900 A.D.	*Abbasid* Caliphs — Baghdad — Haroun al Raschid —*Al-Kindi*, first Arab philosopher — *Al-Khwarizmi*, algebra — *Sufism*, neoplatonist alchemical mysticism.
900 - 1000 A.D.	Break-up of Caliphate — *Alfra-Ganus*, founder of Islamic astronomy — *Rhazes*, medicine and chemistry — *Abul Wafa*, trigonometry — *Al Masudi*, geometry

1000 -1100 A.D	*Avicenna*, medicine and physics — *Al Hazen*, founder of optics — *Arzachel*, elliptical orbits —*Al Ghazzali*, return to mysticism—*Omar Khayyan* mathematics
1100 - 1200 A.D.	*Averroes*, Aristotelian Islamic system
1200 - 1450 A.D.	*Ibn Khaldun*, science of history —*Ulugh Beg*, Samarkand observatory.

II

The Rise and the Stagnation of Chinese Science

At about 830 AD, al-Jahiz in Damascus made a remark which aptly sums up the enigma that is Chinese Science : 'The curious thing is that the Greeks are intersted in theory but do not bother about practice, whereas the Chinese are very interested in practice but do not bother much about the theory.'

The conditions under which Chinese science and technology flourished in ancient and medieval times were quite different from other ancient civilizations. The State was greatly involved in China. It organised the collection of facts, it helped to implement the knowledge thus gained throughout the vast country, as well as in using the perceptions of the scientists to improve its revenues and its ability to wage war. It was this involvement of the State that made the history of science in China so different from that of early science elsewhere. Chinese studies were far more organised, far less sporadic and ideas were more likely to be seen through to completion than the work of the relatively isolated scientists of medieval Christendom. Yet, despite the fact that ancient and medieval China had a glorious scientific and technological tradition, it is at the same time true that modern science, i.e., the testing by systematic experiment of mathematical hypotheses about natural phenomena, originated only in the West. The Scientific Revolution simply did not take place in China. Why did China fail?

Before we try to answer this question, let us first have a cursory look at the great triumphs of Chinese science and technology.

According to Needham, the first reference to alchemy in world history was made by Li Shao-Chun in 133 B.C. Again in 142 A.D., the first ever book on alchemy was written —*The kinship of the three*. This book described the use of chemically transformed substances as the elixirs of life. Needham even suggests that the very word *alchemy* was Chinese in origin. From the Chinese it was taken over by the Islamic Arabs.

On the theoretical front, the earliest Chinese theory supposed the Universe to be composed of two fundamental principles : Yang andYin, light and darkness, male and female. The Chinese Five Elements theory differed from the Indian and the Greek. The Chinese theory talked about metal, wood, water, earth and fire. Pervading everything was *chhi* in various forms — vapour, spirit, subtle influence. It is certain that the first conception of atoms was either Indian or Greek. But the first conception of wave motion was perhaps Chinese.

On the practical front, the Chinese achievements were very remarkable. At about 132 AD, the mathematician Chang Heng invented the first seismograph. It was so constructed that a bronze ball would fall out of the mouth of a bronze animal into a container below. There are records of a carriage which, if set to indicate the south, would continue to do so, no matter in what direction it travelled or changed course. This was not a magnetic compass, but a mechanical device that can easily be called the first of all cybernetic devices. Silk technology, the development of ceramics and porcelain are, of course, well known Chinese technologies. But the three greatest discoveries of the Chinese were paper and printing, the magnetic compass and gunpowder. Paper was first made in China in 105AD. Printing began in about 700AD and movable block printing three centuries later. Gunpowder was definitely known to them by 850 AD, if not earlier.

The Chinese had an enormous pharmacopoeia, which dates back to the Han times. This includes not only descriptions of plants, but of minerals too — something which was not done in Europe until Paracelsus in the 16th century.

Even this extremely sketchy account shows how great the Chinese genius was in science. Why then did it stagnate? It is clearly impossible to give a categorical answer to this question, but it may in part be connected to the same close association of science and the State bureaucracy that accounted for its early achievement. In China, the great impulse to exploration, to new discovery for its own sake never developed as it did in Renaissance Europe. There was no aspiration to break the mould

of existing orthodoxies as inspired men like Galileo. And one of the reasons for that must lie with the prevalence of the efficient but traditional bureaucracy of China, its rules and outlook defined by Confucius many centuries before.

Thus, the reasons for the decline of China's science may be categorized as social and philosophical, reinforced by the geographical factor.

The Socio-Geographic Factor

China is a monsoon country, and the rainfall is far greater in June and July than in other months. It is also very variable from year to year. On this account the Chinese were faced with the necessity of making large-scale irrigation works and mastering water conservancy at a very early date. Their works in that direction are greater than any others, even those of the Egyptians. The Grand Canal (5th century BC to 5th century AD) is one of the greatest hydraulic engineering achievements of the world. It is argued by some Chinese scholars that this necessity had two consequences : in the first place, millions of men, or workers, had to be controlled, and if you have to control such a large labour force you have to have a large body of officials. No one who is not acquainted with Chinese civilization can realise the importance of the Civil Service and the Mandarinate in traditional China. But also the extent of the irrigation to be conducted has to be considered, since if the work is to be effective it had to be done on a large scale. Hence it transcended the boundaries of fiefs of individual feudal lords and became centralised. But the more centralised the authority, the less the power of the feudal lords and the more the power of the Emperor.

Chinese medical practice is a typical example of the bureaucratic nature of their civilization. Medical practice in China was a strictly regulated profession. Examinations had to be passed, in general education as well as in medicine. And by the fifth century AD there were already academic positions in medicine, while by the T'ang age (7th century AD), there was an Imperial Medical College. It seems to have been in China, too, that the

idea of hospitals first arose (1st century BC). They came before the Han, but with the arrival of Buddhism (3rd century AD) their number increased. Originally Taoist and Buddhist foundations, they were taken over by the State from late T'ang times onwards. There were also quarantine, certainly as early as the fourth century AD, if not before, and two hundred years later leper colonies had been established.

All very impressive, no doubt. But all this did not lead to the establishment of a modern scientific theory and practice of medicine, for which once again we had to wait for the European Renaissance and its consequences. State bureaucracy was at once the boon and the bane of Chinese science.

We must also consider the continental character of China as against the peninsular structure of Europe. The characteristic European unit was the mercantile city-state. The European distribution of land and water led very early to an emphasis on maritime navigation and to a mercantile economy. The Chinese solid land-mass, on the contrary, led to a network of towns 'held for the Emperor' by a Governor or Magistrate, and each surrounded by a hundred agricultural villages. One must always contrast the Greek *polis* with the Chinese *hsien*. Now if the Mandarinate was supreme, if the Civil Service was always the great power, there was a bar to the development of any other group in society, so that the merchants were always kept down and were unable to rise to a position of power in the State. This might be the main cause of the failure of Chinese civilization to develop modern technology, because in Europe the development of technology was closely bound up with the rise of the merchant class to power. It is perhaps a question of who is to put up the money for scientific discovery — it is not the Emperor, it is not the feudal lords; they fear change rather than welcome it. But when you come to the merchants, they are the people who will finance research in order to develop new forms of production and trade; and such was indeed the case in Europe. Chinese society has been called 'bureaucratic feudalism', and that may go a long way to explain why the Chinese, in spite of their brilliant

successes in earlier science and technology, were not able to break through the bounds of medieval ideas, and advance to modern science and technology. One of the great reasons is that China was fundamentally an irrigation-agricultural civilization, as contrasted with the pastoral-navigational civilization of Europe; with the consequent prevention of the merchants' rise to power.

As a typical example of this process we can cite the case of the great Chinese admiral Cheng Ho in the early fifteenth century. He sailed the Indian Ocean in fleets of large ships carrying thousands of men, conquered Ceylon, and explored the African coast — and then was deliberately stopped by the authorities! Technically the Chinese could easily have anticipated by a hundred years the exploits of Columbus and the Conquistadors. But they lacked the motive : Chinese economy did not need foreign trade. The most remarkable import was a giraffe, of which the Emperor disapproved. The Chinese Emperor had another and more pressing reason : the Tartar tribes in the northwest were a serious peril and it needed all the resources of the Empire to hold them in check.

The Philosophical Factor

Confucianism and Taoism were the two major Chinese world-views. Both had influenced Chinese science and technology. The Confucian school, which became orthodox, was profoundly this-worldly in their outlook. It desired to organise human society in such a way as to obtain the maximum of social justice, as they perceived it. They emphasised literary as opposed to manual activities, and in fact they built up a sort of 'scholasticism'. For them, ethical behaviour partook of the nature of the holy, but it was not divine and had nothing to do with divinity, since the conception of a creator God was unnecessary in the system.

The Taoists, on the other hand, walked outside society. They reacted against Confucianism. According to them, it would never be possible to properly organise human society, until one knew more about Nature. So they retired to the woods and the mountains and tried to make some examinations of Nature. But

they never developed an experimental method based on hypotheses, and thus they were not able to proceed much further. They were extremely interested in Nature, but tended to distrust reason and logic. In about 290 BC they talked about an interesting doctrine of evolution. They said, animal species are not fixed, but change into one another in course of time.

As an example of the typically Taoist imagination, let us consider the 'Infinite Space Theory' of the universe. It is associated with Ch'i Meng, who lived sometime during 25 to 220AD. This view propounded that the heavens were empty, void of substance and having no bounds. The Sun, Moon and stars floated freely in space. What drove them in their paths? Here the Chinese called on a concept of the 'hard wind'. This idea was derived from the Taoists, and possibly originated in the powerful air blasts of bellows used in smelting. The whole theory was a totally novel idea. Compared with the contemporary rigid Greek belief in solid spheres, it was immensely more imaginative, though tinged with mysticism. At the same time, by finding an analogy with the blasts used in metal smelting, it exemplified the mystical-experimental trend of Chinese thought. Hard empirical experience mingled with rarefied mysticism. Chinese alchemy, too, the oldest in the world, developed in a Taoist milieu. The Taoists were extremely interested in immortality, but they did not want spiritual immortality — they wanted to live on here. They were after a medicine or plant that would give long life. Material longevity and immortality was what they sought. The result was alchemy. However, their disregard for logic and reason, and their predilection for mysticism perhaps stunted the kind of stimulus without which, modern science could not grow.

Another ancient school of thought was that of Mo Tzu. Their school contained a great deal of scientific material, like discussions on optics, and other branches of physics.

A fourth school was that of the Legalists. That school did not succeed because of their association with tyrannical authoritarianism, and that lack of success is perhaps one of the ideological factors behind the failure of the Chinese to develop

modern science and technology. For in European history we find a close connection between the concepts of legal law and natural law. This was not to be found in China.

Thus in China, on the one hand interest in Nature was concentrated purely in human relations and social order; on the other hand interest in Nature tended to be mystical-experimental rather than rational-systematic. To cap it all, there developed a strong apathy for abstract, codified law.

As a combined result of these factors, there developed a sharp contrast between the Chinese concept of Laws of Nature and that of the West. According to the Confucian ideas, the harmonious co-operation of all beings arose, not from the orders of a superior authoity external to themselves, but from the fact that they were all parts in a hierarchy of wholes forming a cosmic and organic pattern, and what they obeyed were the internal dictates of their own natures. Chinese conceptions of law did not develop the ideas of laws of Nature for several reasons. First, the Chinese early acquired a great distaste for precisely formulated abstract codified law. This was the unfoutunate result of the abortive tyranny of the politicians belonging to the school of Legalists. Secondly, the available ideas of a Supreme being became depersonalized soon. These ideas also lacked the element of creativity. Thus, they prevented the development of the conception of laws ordained from the beginning by a celestial law-giver for non-human nature. Hence the conclusion did not follow that other lesser rational beings could decipher or reformulate the laws of a great rational Super-Being if they used the methods of observation, experiment and inference.

To sum up, then, one can say that what the Chinese did do was to classify natural phenomena, to develop scientific instruments of great refinement and to observe and record facts with a persistence unmatched elsewhere. But they failed to apply hypotheses of the modern type, for various social, geographical and philosophical factors. From the time of Galileo (1600 A.D.) onwards, the new, experimental philosophy of the West overtook the levels reached by the natural philosophy of China, leading to

the exponential rise of modern science in the 19th and 20th centuries. As we have hinted earlier, Greek science was fortunate in having able inheritors in Islamic science; Islamic science handed over its treasure to Europe; but Chinese science failed to find a link with the developing new science of Europe. The line of continuity was snapped, and thus it was doomed to stagnation.

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CHINESE SCIENCE AND TECHNOLOGY — IMPORTANT EVENTS

2697 - 2597 B.C.	Observatory —Idea of Cosmos as an organism
2640 B.C.	Silk
c. 1500 - 1027 B.C.	'Pi'-wheel to fix positions of stars —lunation (29.5 days)—solar year (365.25 days)—counting boards — counting rod numerals.
720 B.C.	Solar eclipse records —mechanical water-clock
c. 604 B.C.	Acupuncture and Moxibustion — pin-hole camera
c. 551 - 479 B.C.	Glass —Philosophy of Lao Tze and Confucius
5th c. B.C.	Beginnings of water control (Grand Canal)
4th c. B.C.	Rudiments of soil science —Ox-driven plough — iron tools, weapons — star mapping — concept of Taoist Yang and Yin —study of statics—idea of water cycle —

	rudiments of decimal system —place value notation.
3rd c. B.C.	**The Great wall** —study of tides —first hygrometer —Botanical two-name nomenclature —Treatise on Medicine —book on Arithmetic — solution of simultaneous linear equations —rudiments of co-ordinate geometry —magic squares —powers of 10 —value of pi — **Infinite Empty Space theory of the Universe**
2nd c. B.C.	First seismograph —kite flying —circulation of blood —Sun-Tzu's *Arithmetic* —reestablishment of Confucianism as official philosophy
1st c. B.C.	Sun spot (28 B.C.)— hospitals — civil service examinations.
25 - 220 A.D.	Paper — stills
3rd c. A.D.	Knowledge of fossilized pine trees
5th c. A.D.	Proto-compass —horse harness —parhelia described —**GRAND CANAL** completed from Loyang to Hangchou
7th - 9th c. A.D.	Geographical maps —block printing —**gunpowder** — study of flat and concave mirrors — Imperial Medical College —Medical College Exams —T'ang dynasty
10th c. A.D.	**Mariner's compass** — Pascal's triangle
11th c. A.D.	Supernova explosion described (1006) —Geological theory of development of mountains from sub-sea land.

Notes on the GRAND CANAL

— largest in the world (c. 1000 miles —extending from Hangchou to Peking)

— started in 6th *c*. B.C. and completed over a period of 2000 years

— built by dredging and linking existing canals

— tree-shaded roads, postal stations and imperial pavilions along the canal

— disrepair between 10th and early 13th c.

— reconstruction and extension by Kublai Khan (13th c A.D.) up to Peking

SECTION - III

SCIENCE & TECHNOLOGY IN THE PRE-MODERN & BRITISH PERIOD IN INDIA

III - 1

AN ASPECT OF ARTISANAL TECHNOLOGY IN INDIA — SOME METHODOLOGICAL ARGUMENTS

SMRITIKUMAR SARKAR

Artisans, still constituting an important segment of Indian society, represent the single largest element of continuity of the *Lokavidya* or the 'living traditions of sciences and technologies'. The continuity has been attributed to the 'survival of subsistence households of simple commodity producers, surviving by dint of superhuman exploitation of family labour and undergoing continuous immiserisation'.[1] The artisan as practitioner of *Lokavidya*, therefore, has been the tragic hero fighting his lone battle against the *Jaggannath* of heavy machine indistry.

The artisan constituting an organic element of Indian society had extremely important role in its transition. Even in these days of globalisation and open market their relevance to the South Asian economy could hardly be denied.[2] The conventional notion of unchanging artisanal technology in India largely contributed to the neglect of the artisans as a social force, passive and quite immune to the changing requirements of the market. The notion has not been seriously examined even in the post-colonial period. The present essay on one aspect of artisanal technology is thus situated in this perspective. Based on the 'tribal' blacksmiths working in an isolated region, this could also help find out the options, which are still open to us and which could suggest new insights into some of our present-day problems.

Artisan in Indian History

The question of artisanal tool-technique in India has been an important subject in understanding the development of indigenous technology and its role in the historical process of social transition in South Asia. Unfortunately, however, the subject has been only inadequately studied so far, the inadequacy being an outcome of the neglect of artisan as a subject in the present day Indian historiography.

The point is does India's handicraft sector really deserve this neglect. The available estimates, although inadequate, clearly suggest a bigger role for the Indian handicrafts both in terms of employment and output. In 1750, India perhaps supplied 'a quarter of world production of manufactured goods' while in the greater part of the nineteenth century the manufacturing activity remained largely confined to handicrafts.[3] In 1901, the large-scale industrial sector in India, including mining and small-scale industries, thus appears to have employed a little over four per cent of the country's manufacturing workforce, rising to nineteen in 1947.[4] In 1931, for instance, large-scale industries employed much less than one per cent (0.42%) of India's total population,[5] while its contribution to the total income from the secondary sector in terms of 1938-39 prices increased from 19 to 53 per cent only between 1901 and 1947.[6] Even in 1947, therefore, eighty per cent of the workforce connected with the manufacturing activity were employed in the handicraft sector, indicating the importance of its role in determining the structure of Indian economy throughout this period, adverse impact of colonial rule notwithstanding.

Studies on Indian artisanal production have largely based on de-industrialisation. Deep-seated into the consciousness of Indian historiography, the debate on de-industrialisation had its origin in the mid-nineteenth century disillusionment with British rule in India. The early decades of the nineteenth century had witnessed the emergence of new manufacturing units like Fort Gloster, flour/sugar and rice mills or the steamers sailing down the Ganges before the wonder-struck eyes of its innumerable

bathers along their routes from Calcutta to Patna. All these had created a notion of an imminent Industrial Revolution in India; yet the real situation was nowhere near this expectation.[7]

It was this frustration, analysed in the light of Marx's oft-repeated comment about the impact of British steam and science on Indian economy,[8] which had eventually crystallised into an ideological construct of colonial disruption. That free import of English manufactures into India would ultimately lead to re-ruralisation of the Indian economy by destroying its own industrial structure. The nationalist leaders eventually made it the main plank of their argument against British rule in India; the imperial protagonists of the Raj naturally took up the defence counsel. Since then, the issue of de-industrialisation has been variously used by its exponents to explain the backward condition of Indian economy, making it almost the legion of Indian economic history.

This debate as such is not important for our discussion; nor does it want a resolution on the all-important question connected with this debate as to how far British rule was responsible for undermining the existing structure of the Indian economy.[9] The debate has been referred to here only to draw attention to the fact, this long-drawn debate involving a number of internationally-known historians has failed to extend the frontiers of our knowledge regarding the Indian artisans, yet the question of Indian artisan lay at the centre of this debate. One of the important reasons of this failure was the pre-occupation of the concerned historians with the micro-economic issues and their failure to enter the actual domain of the working artisans. In reality, different objectivity, the use of the same kind of source materials by historian both supporting and opposing the argument of de-industrialisation and the particular research methodology used to support their pre-conceived conclusions mainly stood in their way of looking at the small domain of the Indian artisan. I would return to this point while discussing the research methodology.

Apart from de-industrialisation, the question of artisan has also surfaced in the discussion of the Indian village society, of which

the artisan naturally formed an inalienable part. Historians and social-anthropologists have variously tried to define the village society's relationship with the artisan yielding a very good crop of literature on the subject. Nevertheless, this discussion has largely concentrated on the mode of payment the village artisans used to receive in return of their service to the village society. Artisans in general lived in the village and pursued their crafts in response to the demand of the village society. The nature and amount of their returns, their relationship with the village society and above all the difference in the village society's treatment to different artisan groups are some of the questions that have received primary attention of these scholars.[10] As in the case of the de-industrialisation debate, therefore, the working domain of the actual artisans has been largely neglected here.

Artisans Reconsidered

The point is the long-drawn 'statistical exercise' either to establish or to refute the argument of de-industrialisation has its own limitation. This is also true of the theoretical exercise to define the village society's relationship with the artisan. Although these debates enriched Indian historiography, neither of them actually helps us very much to know the diverse nature of the pre-modern industrial production in India. Not unnaturally, therefore, the actual domain of the artisan's work, tools and implements used by him, the technique of production and above all the artisan's perception of his work, notwithstanding the conventional notions regarding the artisan's craft in India, remain largely unknown.

In one sense, this limitation is largely due to the nature of sources and the research methodology used in earlier studies on Indian artisans. In most cases, these studies were based on the accounts left by foreign observers, which concealed much more than they actually revealed since these observers did not have access to the real world of the artisan's work. Many things stood in their way : the observer's power and position, his upbringing and cultural background and above all the cultural-ecological environment of the actual artisan working in his field. The

motivation of such accounts was also different, dealing largely with broad outer aspects of craft production mostly ignoring the artisan's own perception of the work.

The commercial interests had in the beginning drawn European attention to the wonderful world of Indian handicraft production, records of the European companies remaining as its best example, but they dealt mainly with the textile industry since it was the primary concern of the early European commercial enterprises in India. In the later period, however, their attention shifted to some other Indian industries till the Industrial Revolution had altered their position.[11] A shift in government policy at the end of the nineteenth century once again drew attention to Indian artisans, producing a number of extremely useful monographs on inportant craft activities followed in different parts of India; but the policy did not last long.[12] Thus, one could hardly hope to get into the actual working world of the Indian artisans simply by depending on archival documents and similar other evidence used in historical research.

Research Methodology

I would like to start with a brief note on artisanal technology by referring to the conventional notions of what is actually meant by technology. The technique usually followed by an artisan in producing his goods has been described as the artisan technology. We can also call it as his tool-technique. If the artisan himself collects his raw materials, his working technique starts right from that moment, since he has to plan his material collection with an eye to the shape of the finished ware, also keeping in his mind the amount of wastage involved in the process of production. Thus, the artisan not only has a clear conception of his craft but also a pre-conceived notion of the working method, which is an important part of what we call artisanal-technology.

Where the artisan gets the supply of his raw materials from his customer, the prior planning of his work remains equally important because he has to calculate the volume of materials required for his work well in advance the production process actually sets in

Production also involves a good deal of calculations and measurements often made in the artisan's own working language and gestures, and hence not intelligible to an external observer. This is particularly true in the case of the metal craft necessitating preparation of the metal lump before its fabrication; involving a number of inter-linked processes, usually kept a closely-guarded secret by using working formulae, metaphors and similes and handed down to the next generation. All these form inalienable parts of the artisan's technology.[13]

The latter also includes various tools and implements used by the artisan, their shapes and designs, widely varying nomenclatures to describe their tools or parts thereof, the similes and usage, which clearly remain by far the best reflections of the artisan's perception level, hence closely related to his working technology. One can thus hope to locate the real artisan only by taking all these inter-related aspects of his work into consideration.

Equally important is the artisan's relative position in the hierarchical structure of the craft he actually belonged to. It appears that the working site and the workshop design, which the social-anthropologists always attach great importance to, are clearly relevant to the study of his working technology and socio-economic position. Different groups of artisans engaged in the same craft thus appear to have different workshop designs, as we would see here with reference to the primitive blacksmith of our region, this difference being extremely relevant to understanding their technology. Apart from the design of their workshops, sometimes working tools also varied with different groups of the artisan working in the same craft even when they used same tools their nomenclature differed. In the present discussion, therefore, craft-technology includes all these minute aspects associated with the artisan's craft and not only the outer and hence invisible aspects of his work.

This methodology has not been followed in the existing works on the Indian artisan. The present paper is a modest attempt to supply this missing perspective in the historiography of Indian

artisans and craft-technology. But, before we do that a brief reference to the existing notions of craft-technology generally in use in Indian historiography may be useful here.

Technology used by Indian artisans is widely believed to be very simple, backward, stagnant and devoid of any scientific basis.[14] The emphasis has been generally on the stagnant character of this simple and backward technology. From Max Weber to most other international and national scholars interested in this field has, therefore, accepted the notion of the unchanging Indian craft technique, not responsive to market demand.[15] The unchanging craft technique has been variously attributed to the other-worldly nature of Indian way of life and Indian culture, Hindu theology and the rigours of the caste restrictions, while some others have held the Indian social system responsible for it.[16]

The details of these arguments can not be discussed here, their basic point is total technological stagnation conducive to the preservation of the old order in Indian industrial production for centuries. Even a distinguished historian like Irfan Habib came very close to subscribing to this conventional notion. Significantly, in some places he has opposed the idea of total stagnation but he has not been very emphatic in his denial. As such he does not seem categorically clear on the point of change. In fact, he has pointed out that Indian society had very little disposition towards technical change unlike China or similar other countries, which according to him were one of the main obstacles to the growth of capitalistic development in pre-colonial Indian economy.[17] By suggesting the absence of 'inter-sectoral diffusion of tool-techniques' in Indian industrial production, therefore, he has practically accepted the conventional argument of technological stagnation.[18] Because of their frequent repetitions, these arguments have been widely accepted as theories, although in most cases they are not based on serious research into the actual domain of the artisan's tool techniques.

In reality, these theories have been the outcome of what has been described as the 'Whig historiography of industrialisation'. Constructed upon the specific reading of historical developments in Western Europe,[19] this historiography considers industrialisation as a process of evolution from the handicraft industries. Since this evolutionary schemata does not fit into the Indian context, this historiography has led to the neglect of paying proper attention to India's handicraft sector. Even when it does, it considers the question of the traditional technology in India from the point of view of the late eighteenth century England's take-off to industrialism. In fact, not only India, viewed in this perspective, the pre-modern production system in most regions of the world would seem stagnant and backward. One of the recent historians of technology has thus described this methodology as one of comparing the utility of an abacus with that of a microcomputer or a candle with an electric bulb.

The indiscriminate use of these two terms, often made without a reference to the well-known debate among French scholars on their use and applicability, has created a lot of problems in understanding the nature of tool-technique pre-existing the Industrial Revolution. The latter had not only revolutionised the productive processes, but had also considerably widened the man's ideas about it. With this revolution also came the popular use of the term 'technology' in the sense it is understood today. In its present use, technology incorporates nearly everything relating to mechanical operation of a bicycle to that of a million-dollar satellite. Sometimes, the same term is used even to mean the working of the weaver's loom or the blacksmith's bellow. Although it has simplified a complex reality, such simplification has often created problems. This is indicated by the recent coinage of terms like 'intensive-technology' or 'higher-technology', intended to isolate the process thus indicated from 'technology' in the sense it is usually taken today.

In reality, the problem had its origin in English translation of the continental term *la-technologie*. In the European mainland, the term *la-technique* in French, German and Slav languages is

used to mean 'all activities associated with things technical', while the term *technologie* usually refers to 'the specialised and advanced stages of *technique*'. Naturally, the term *technologie* in European languages is applied in a restricted sense, unlike its use in English language, while that of *technique* had a more universal application. In England, the term technology usually stands for both *technologie* and *technique* of the Continent in the absence of an appropriate English equivalent of the term *technique*. Jean-Jacquessalomon in his essay 'What is technology?' has beautifully described this problem as 'the difficulty in crossing the Channel'.

In order to further define the nature of this problem, he has referred to Fernand Braudel's definition of the material civilisation and its translation in English. Braudel wrote in French : 'In a way, everything is *technique*', followed by a long list of examples, 'none of which relied upon current scientific ingredients of what may be today understood as technology.' The passage was translated in English : 'In a way, everything is technology : not only man's most strenuous efforts to make a mark on the external world; not only the rapid changes we are a little too ready to label revolutionary (gun-powder, long-distance navigation, the printing press, windmills and watermills, the first machines) but also the slow improvements in processes and tools, and those innumerable actions which may have no immediate innovating significance but which are fruit of accumulated knowledge : the sailor rigging his boat, the miner digging a gallery, the peasant behind the plough or the smith at the anvil.'[20]

The use of the term technology for both *la-technique* and *la-technology* has thus created a problem of distinguishing technique from technology. In a way it has also influenced our historiographical consciousness. Thus, whenever we try to characterise the production process of the earlier societies as either backward or static, we have in our mind a comparative frame, always looking for what Braudel called rapid if not evolutionary change. What is neglected, therefore, is the all-important perspective of time and society relative to such production process.

Much of the confusion in understanding the technical nature of craft-production in India, as discussed earlier, have thus resulted from the conceptual problems arising out of the all-pervasive use of the term technology. It is, therefore, necessary to identify the scope of the term technology when we apply it to the study of the production technique of the earlier societies.

In the following discussion, however, the term technology has been used in the continental sense of technique or *la-technique*. In other words, we have accepted here anthropoligist Marcel Mauss' interpretation of the latter term, referring it to 'the doing and making' in ancient and traditional societies. Significantly, in Sanskrit-based Indian languages it is easier to express this distinction, thus Niharranjan Roy used the term *krit-kaushal* to mean craft-technique as distinct from *prajukti* or the advanced stage of tchnique : technology or *la-technologie* of the Continent.[21] However, others did not follow his example, not even the learned colleagues of his own province, because in history we are used to follow 'the western model' only and the English in particular in historical research. It seems the colonial hangover still haunts our consciousness.

The research methodology followed here also needs a little elaboration. In this essay, I would refer to some changes in craft-technique : changes that would otherwise seem trivial and meaningless but were nevertheless extremely important in the context of the particular time and society they took place. In order to emphasise this relationship between the change in craft-technique and its social perspective, I would refer to two examples. Historians of medieval Europe has characterised a particular period of its economic history as the era of 'pre-industrial rise', that is 'more than a craft but less than an industry of the modern kind'.[22] The basis of this 'pre-industrial rise' was an important change in contemporary craft-technique : the invention of the spinning wheel and the use of pedal loom instead of the conventional handloom. The contemporary society of Europe could absorb such changes because it needed them in the wake of the commercial revolution.

But when in the end of the seventeenth century, the English merchants tried to introduce improved models of loom from Holland to the English woollen industry, English craftsmen reacted with widespread riots. Thus the enterprising merchants had to give up in view of the persistent opposition of the English woollen workers. It indicates, among other things, the difference in the objective conditions of production between the late seventeenth century Holland and England. Not unnaturally, therefore, many of the contemporary observers had remarked that if an industrial breakthrough ever took place in Europe in the near future, it would happen in Holland and not elsewhere. The point that needs to be emphasised here is the close interrelation between the particular technique of production and its social perspective.

A change in the technique, imported or innovated locally, therefore, must have to be socially receptive, and the impulse for such change must always come from within the society and not otherwise.[23] The degree of such change is also relative, it may be trivial to an external observer, yet may be extremely relevant to the production system of which it is a part. It is this perspective which is largely missing in the study of craft techniques in India, and that is why we have followed it here. One of the reasons why the study of craft technique still remains a neglected subject in Indian historiography is the non-availability of necessary data. The difficulty of analysing artisanal tool technique, within the limits of the conventional time brackets used in history, is also fairly well known.

There may be two ways of looking at the artisan's working technique, his tools and their uses. The most widely followed method is to analyse them in the context of the particular technological level of the society he belonged to; thereby determine the quantum of filtration of such knowledge and the amount of its influence on the artisans. Here the artisan is portrayed primarily as the beneficiary of the knowledge evolved at the higher level in an otherwise integrated structure. The artisan's relative position thus depends on the nature of social mobility as also the supply of labour as a factor of production.

The other way is to consider the question of craft-technique from the view point of the actual practitioner. The artisan uses his tools to minimise his labour input per unit of production; but his perception of utility of tools is relative to the social context of the production process he is actually associated with. Hence, this perception, even with regard to the same tool could vary from one artisan group to the other. The artisan has the working knowledge of his own and the method of its representation; tools are thus often identified with gods and their mythical heroes. By analysing the myths and legends associated with artisanal crafts, and their workshop designs in particular, using the methodology of the social anthropologist, one can thus get an insight into the artisan's own logic of changing their craft technique. The following discussion is largely based on this methodology.

Theme of Discussion

i) Workgroup : primitive blacksmith

The pre-colonial craft production in India was extensively large and diverse in nature. For our convenience, therefore, only one workgroup has been selected as the theme of the present discussion, namely the blacksmith. The blacksmith's was an extremely important craft. Apart from its material basis, the close association of iron with rituals relating to nearly every occasion from birth to death of an individual's life in India symbolises the importance of his work to traditional Indian society. The blacksmith's craft was divided into two distinct branches. First the reduction of iron ores and the making of the virgin iron was a location-specific activity, usually undertaken by iron smeltng tribes and restricted to certain regions, where iron ore was not only available but also easily accessible to pre-modern mining techniques.

The second, the more diverse and the widely varied activities of forging to produce tools, weapons and other objects of iron, was directly related to and largely dependent on the former. India was one of the few countries of the pre-modern world, which not only produced an excellent quality of steel but also regularly exported it to outside.[24] And since it did not import iron, unlike

England or similar other countries, the entire quantity of metal must have been produced by the Indian smelters themselves. The smelting and forging of iron, although interrelated, were nevertheless two distinct occupations usually followed by separate workgroups. The workgroup chosen here also needs an explanation.

Unlike textile weaving and similar other consumer goods industries, the demand for the blacksmith's craft did not expand very much. Hence, the industry could retain much of its traditional structure till the import of iron and steel from England in early nineteenth century had reversed its position. The industry thus offers a rare opportunity to study the evolution of craft-technique over a long period of time. In textile weaving, the traces of primitive production functions nearly disappeared with its massive expansion in the pre-colonial period. Not so in the blacksmith's craft. At the higher level of this craft-structure, there were fully market-oriented workgroups depending on merchant capital. But at the same time, craftsmen still clinging to primitive production functions and catering to an essentially limited demand of their immediate neighbours, could be found at its bottom. The present essay intends to highlight the changing pattern of the blacksmith's craft technique by comparing craftsmen working at different levels of the production organisation.

The choice of this craft has been also dictated by its close relationship with the tribal society, not found in the case of most other crafts in India. From ancient times, the mining and smelting of metals in India had been the specific occupation of the numerous workgroups belonging to that part of the Indian population, presently known as 'tribes' living in different parts of the subcontinent. Not unnaturally, they lived outside the mainstream society; recent research has revealed that even within the tribal society they had a very low social position.[25] This has helped the blacksmith's craft to largely retain its primitive identity, drawing research attention of the early anthropologists. The accounts left by them have not been properly used so far.

ii) Area : iron-tract (Loha-mahal)

The choice of the area in a study of this nature is often dictated by the availability of its sources. Traditional iron smelting was practised by numerous tribal workgroups living in different parts of eastern India. For the present study, however, I would concentrate on the contiguous areas from the Santal Parganas and Chotonagpur to Birbhum of the present-day Bihar and West Bengal states of the Indian Union. The indigenous manufacturing of iron in this region was one of the important non-agricultural occupations till the early nineteenth century. Some other areas of Orissa and Madhya Pradesh have been also occasionally referred to by way of comparison.

The archaeological remains of ancient copper and iron smelting sites found in this region indicates the antiquity of its metallurgical tradition. Geologically also, the region is distinguished by its rich mineral deposits, particularly iron ore. Not unusually, therefore, in popular folk traditions and local usage the region has been known as the *Loha-Mahal* or literally iron tracts. Unlike in South India, however, the penetration of merchant capital into the manufacturing of iron in this region was a late pre-colonial development.[26] As such, market forces had affected the primitive organisation of iron smelting in this part of India much less than it did in the south. The early colonial records thus frequently refer to the co-existence of various workgroups working at different levels of this craft-organisation.

The region has also a high concentration of tribal population. The historical process of change in similar societies is pertinent to any discussion on craft technology. Anthropologists broadly agree with the view that primitive societies all over the world sometimes had a direct transition from pastoral nomadism to migratory craft occupation. This is particularly true of the case of the mining and smelting of metals. This inter-relationship has been discussed earlier.

The point, which deserves attention here is that the study of the process of transition in a primitive society could provide useful

clues for analysing the early evolution of craft, tools, for which we have very little direct evidence of empirical nature. D.D. Kosambi applied this methodology to analyse the evolution of societies in ancient India.[27] This methodology could be more usefully applied to the study of craft technology. India like any other ancient composite civilisation offers a unique opportunity to study the still 'surviving backward social clusters' for understanding the production techniques of the earlier period. The available indications could be compared with whatever little evidence we have on the subject. Unfortunately, however, this has not been tried very much in historical research.

iii) Background : tribal society

The primitive society has yet another relationship with the blacksmith's craft. In early societies the world over, the blacksmith and the metal he worked with had a special position not comparable with other craftsmen. This is clearly reflected in their myths and rituals, social customs and habits; the tribal societies in India are no exception to this general pattern. The close association of iron with rituals from birth to death of an individual in India, as stated earlier, is evidence in point. In the case of the tribal society this association is relatively stronger. Significantly, the popular notion of iron and the blacksmith varies from one group to the other even within the same region,[28] a full-scale discussion of which would be out of the scope of the present discussion.

In brief, the primitive blacksmith all over the world was both respected and feared, since his metal was considered sacred; and like all other sacred objects it was both 'dangerous and beneficent'. At the root of this widespread belief was the notion of the celestial origin of iron and the consequent faith in its magical and healing properties.

The ritualistic use of iron pre-existed its secular use and this had naturally started with meteorite metal, believed to be of extreme spiritual value, long before the manufacturing of iron by primitive blacksmith. With eventual development of his

technique, most of the pre-existing notions relating to the virgin and celestial iron had been slowly bestowed upon ferrous iron. The primitive blacksmith's association with this all powerful metal, particularly his ability to deliver it at his will, naturally distinguished him from other people.

The distinctive character of his position compared to most other craftsmen is also evident from the existence of numerous stories and myths woven around him. This is largely true of most of the primitive societies. Some of these stories found among the *Mundas* of eastern India have been used here to analyse the early development of mining and smelting techniques in this region, following the methodology used by the social anthropologist. The possible indications derived form these sources have been compared with other empirical evidence where available.

The Changing Pattern of Craft-Technique

i) Primitive blacksmith : Asur-Agaria

The antiquity of the *loha-mahal's* association with iron manufacturing is difficult to state with any amount of certainty. In the oral tradition of the local tribes, a small group of adivasi blacksmiths known as *Asur* are believed to have introduced the craft of iron smelting in this region. In their myths and legends, the *Asur* relate themselves to an origin external to the *loha-mahal* of popular perception, while their kinsmen the *Agarias* of Central India believe to have their original homeland somewhere in the present-day Rajasthan. However, the available indications are fairly clear enough of the *Asur's* very old association with the craft of iron working. In the late nineteenth century, Hoffman described the *Asur* as 'a quickly disappearing group' confined to the areas of Sarguja, Jashpur, and the forest areas of Daltonganj.[29]

The fact that of the different blacksmith groups operating in this region, only the *Asurs* enjoyed the status of the primitive smith also points to the primordial nature of their occupation. In the myths and narratives of the *Mundas*, the dominant tribal group of the region, the *Asurs* have been described as the primitive

smith, so much so that the term *Asur* and the blacksmith are synonymous to them. The kinship and oral accounts of the *Agarias* of eastern and central India also point to this relationship. The term *Agaria* actually means the 'fire-user', or the people skilled to use fire. In the perception of other tribal groups, therefore, the traditional occupation of the *Agarias* was to smelt metal by using fire.

Significantly, the *Agaria* claimed in their myths and legends that they had learnt the craft of iron smelting from the primordial *Asur* smith. In their rituals, therefore, the *Agarias* worshipped the *Asur* as the creator of both fire and iron. The subject of the present discussion does not necessitate an elaboration of the rationale behind this widespread belief for obvious reasons. Nevertheless, the reference to this oral tradition has been made here only to indicate its acceptance by most of the tribal groups of this region.[30] On the basis of this widespread belief, therefore, the *Asur* have been described in this essay as the primitive blacksmith and their craft technique as a possible index of the primary state of the technique of iron-smelting in this region.

ii) Primary stage of iron-smelting technique

It is difficult to state the nature of tools used by the primitive blacksmith of eastern India although it is fairly certain that they had only few tools of the most primitive kind. The traditional image of the blacksmith as the supplier of tool to other artisans also possibly suggests that he must have also fashioned out the tools needed by him. It is interesting to note that the imageries associated with tools used by the traditional blacksmith groups of the *Asur* and *Agaria* describe only the hammer and the tongs as sacred, and not the furnace and bellow without which metal working is unthinkable today. The point which deserves attention here is that the absence of a similar reference to the useful tools of the furnace and the bellow is deliberate and not a fictional slip. In fact, the primitive blacksmith had his earliest association only with the hammer and the tongs; hence they were sacred to him. A clear evidence of this point is the *Agaria* ritual and the

worship pattern. In their *Aayudh puja* or the festival of tool worship held during the month of *Phagun* (February-March) every year, the *Agarias* offered their prayers addressed to their hammer and the tongs only and not to the furnace and the bellow, more symbolic of their craft.

The imageries associated with the blacksmith's tools and their perception of the evolution of their work could be taken as the possible reflection of the primary state of the iron-working craft. It appears, therefore, that the primitive blacksmith had hardly any need of tools other than his hammer and the tongs. In the beginning, the primitive smith made a heap of logs and twigs over the site where he found the ores and smelt the metal in an open and uncontrolled fire, much in the same way his counterpart used to fire the pots. Any stone that he found in its vicinity would have served him as his anvil. Even in the late eighteenth century, the tribal blacksmiths working at the lower rung of the industrial organisation were found to have been using the same method to meet the essentially limited demand of their craft.

The use of the furnace as a means to control the fire and the more efficient smelting of the metal must have been, therefore, a later innovation to which the bellow was added at a still later stage. Initially, the furnace and the bellow used by the blacksmith were of a temporary nature. He made them at the smelting site and deserted them when he left the place in search of new sources of iron ores and his fuel. The differences, which thus distinguished the bellow and the furnace from his other tools, notably the hammer and the tongs, was the perishable nature of the former. Unlike the latter, therefore, he always carried the hammer and the tongs with him from one working site to the other, hence the close integration of these tools with his craft perception. In view of the early development of his tools, therefore, it is not difficult to understand the sanctity of the hammer and the tongs to the primitive blacksmith.

The primary phase of the iron-working technique has to be understood in its social context. The blacksmith during this period

essentially lived a nomadic life. Many things contributed to his nomadism. The limitations of the early technique had restricted all earlier mining activities to surface level only. Since the primitive miner could not dig vertically he had to always migrate from one place to the other mostly in search of iron ores but sometimes also for fuel. The demand for his craft in those days was also very limited. The limited demand and its relatively inflexible character thus forced him to move from one agricultural settlement to other in search of new clients. The pattern of agricultural settlement on the one hand and the availability of iron ores at the surface level on the other, its visible signs in particular, actually determined the course of his migration. In fact, such migration formed an essential part of their social evolution, which I have explained elsewhere.

In the case of the primitive *Asur* blacksmith, for instance, the route of their migration extended from the *Loha-mahal* in eastern India to Karnataka in the South. Similarly, the *Agarias* in their legends and narratives claimed their descent from western India. The *Garulia-Lohars* (blacksmiths on their cart) of the latter region, however, continued to cling to their ancient migratory habit, although the *Asur* and the *Agaria* blacksmiths had eventually reconciled to their sedentary craft life combined with partial agriculture. While moving from one place to another, the nomadic blacksmith groups kept with them their hammers and the tongs. The furnace and the bellow were almost always constructed at the working sites.

The destruction of the bellow and the furnace before leaving the working site thus formed a part of their craft culture. The technique of manufacturing bellow as described in the *Asur* narratives also supports this contention.[31] The limited nature of their inputs, an outcome of the limited demand of their craft wares, thus added to their flexibility as a migrant workgroup. Even in early nineteenth century, the blacksmith at the lower level of the craft organisation was found to have been still clinging to this craft culture. In fact, catering to an essentially limited demand of the small agricultural groups in the remote areas of *Loha-mahal*, they had hardly any reasons to upgrade their craft-technique.

iii) Expansion of craft and the early signs of change

In most cases, however, the nomadic blacksmith's increasing contact with numerous agricultural groups had profound impact both on themselves and their craft. One possible impact of this contact was the eventual diffusion of their craft technique among the non-*Asur/Agaria* tribal workgroups. Their increasing overtures with agricultural settlements brought about important changes in the technique and culture of their craft. I would analyse the nature of this interaction and its impact on the blacksmith's craft with reference to the early phase of the *Munda-Asur* relationship. The *Mundas*, primarily an agricultural people, were the most numerous and the dominant tribal group of the region known as *Loha-mahal.*

The services of the *Asur* as the primitive blacksmith of the region were indispensable to the *Mundas* for the regular supply and maintenance of whatever little iron tools they needed for their sustenance. The interdependence of the two groups over a long period of time had brought about important changes in the life of both the groups. Thus the *Asur* eventually adopted the dialect of the *Mundas* sacrificing their own, and combined their traditional occupation, slow and unnoticed, with agricultural activities they had learnt from the *Mundas.* Similarly, the *Mundas* mastered the *Asur* craft, initially to meet the urgent demand of repairing their tools, but also smelting and manufacturing iron at a later stage. Based on sedentary agriculture, the *Mundas* considered the nomadic *Asur* as the *Baraeko* or an outsider. Not related to their kinship, the *Asur Baraeko* paid only occasional visits to the *Munda* village to procure food crops in return of their services.

Not unnaturally , there was an element of uncertainty in the *Mundas'* dependence on the nomadic *Asurs* for the supply and maintenance of their tools. With the growth of population and expansion of their original agricultural settlements, the *Mundas* could no longer afford to depend on a small group of the nomadic *Asurs.* The services rendered by them were extremely useful but unpredictable. More so, the need to repair their tools could

not be always planned and sometimes needed urgent attention. All these necessitated the existence of blacksmiths, their number actually depending on the size of the agricultural settlement, at the beck and call of the *Mundas*. It was this necessity which led to the emergence of a distinct blacksmith group known as the *Barae* from within the *Munda* tribe. This is not the place to discuss whether this group was a breakaway faction of the nomadic *Asur* smith, who had later on switched to sedentary life, or the innovative *Munda* craftsmen trying with a new occupation unlike their other tribal fellows. The point is how far the diffusion of the *Asur* craft among the non-*Asur* tribal groups was important for the craft-technique of the pre-modern iron working in India.

The *Barae* like the *Asur-Baraeko,* was a miner, smelter and the manufacturer of iron-all in one. But unlike them, the *Baraes* were not nomadic and as *Munda* kinsmen lived within the precincts of the *Munda* village. Hence, the *Baraes* had an altogether different social motivation. As a sedentary group they had a definite demand for their craft bringing about slow changes in their craft technique. The *Baraes* worked in permanent workshops in sharp contrast to the unorganised, open-air works of the *Asurs.*[32]

The characteristic feature of the *Barae* workshop was the development of a stable furnace, which could be used repeatedly in sharp contrast to the one of the *Asurs*. The imageries associated with the *Barae* tools, therefore, do not distinguish the hammer and tongs from similar other tools used by them. In the *Barae* craft-culture, we have thus for the first time a complete picture of the primitive blacksmith's workshop. The available indications are fairly clear that the *Baraes* succeeded in developing a distinct type of the furnace for their use. Nevertheless, it is difficult to elaborate the point any further. However, there is hardly any doubt that the sedentary village smith had an important contribution to the development of small stable furnace known as *saal* in the local dialect. Throughout the *Loha-mahal, saals* were widely used in this region till the late nineteenth century.[33]

The *Barae* workshop could be also distinguished by its bellow. In order to meet the requirements of their stable furnace, they must have tried to evolve a more efficient bellow. It seems the use of animal skin as the bellow cover, replacing the earlier medium used by the primitive smith, was also a *Barae* innovation. The transition form the leafy bellow to the skin-covered wooden bellow must have been a long drawn process. At the present state of our knowledge, it is difficult to state when and where did this important change actually take place?

However, the difference in attitude to their bellow between the *Barae* and the *Asur* seems to suggest that the bellow used by the former was characteristically different from that of the latter. Thus in their craft perception, the *Baraes*, unlike the *Asurs* as stated above, placed an equal emphasis on their tools except the anvil. It seems they were yet to dissociate themselves from the stone anvil used by the primitive blacksmith. The dissociation was difficult. Because, most of the primitive societies used large stone blocks in their rituals. The continuous use of stone anvil by the *Baraes*, notwithstanding their improvement in other tools, might have been, therefore, influenced by their ancient belief. We would see later that only the blacksmiths integrated to larger market networks and backed by merchant capital could afford to ignore it while switching to other type of anvil.

As sedentary craftsmen, the *Baraes* were based in the village having a regular well-defined relationship with its dominant group. The *Baraes*, the *Asurs* and the *Agarias*—all of them were blacksmith engaged in smelting and manufacturing of iron but the *Mundas* recognised the *Asur* only as the primitive smith possessing a supernatural magical and healing power. This is an indirect evidence of the relatively later origin of the *Baraes*. The improvement in the *Barae* craft technique had influenced the *Asur/Agarias;* the eventual improvement in the pattern of the bellow used by the latter group is a case in point. The early nineteenth century field survey thus found the *Agaria* blacksmith using a kind of twin bellows, which, although not technically much different, were more efficient than the primitive bellow of

the *Asur Baraeko.* The design and shape of these bellows widely varied according to the craft culture of various sub groups within the larger cluster called *Agaria* tribe, a point not relevant here.

Significantly, the *Asur* narratives do not refer to these twin bellows, not even to the technique of pedalling the bellows. In view of frequent reference to these bellows in the tribal folk tradition, all these appear to have been of later innovation. In the *Agaria* working songs, therefore, the *Agaria* blacksmith states in an ecstasy of his work, 'My wife presses the bellow with all the strength of her feet, while I hammer the iron with all the prowess of my muscles'. The point, which deserves attention here, is the domestic organisation of the later day *Agaria* craft, not to be found in the nomadic craft of the primitive blacksmith. In fact, the improvement of the craft technique was not possible without an expansion of its demand. The transition of the blacksmith craft from the primitive *Asur* to that of the sedentary village based *Barae*, therefore, must have taken place in the context of a similar expansion in the demand for iron. A much larger expansion, however, took place at the later period, affecting not only the technique of production but also the entire organisation of the traditional iron-smelting activities in this region. This is the theme of the following discussion.

iv) Expanding demand for iron

So far, we could not relate our discussion of the changing craft-technique to definite time periods for the obvious difficulties of using evidence mostly of conjectural nature. Our primary intention was to draw an outline of the historical process of change, which must have taken place within the tribal society of this region over a very long period. To what extent this process had been encouraged and abetted by the larger market forces also remains difficult to state. Certain indirect indications, however, suggest that iron produced in this region catered to demand of an extensive market.

For instance, the coinage of the term *Bangla-Loha* (Bengal iron) and its synonymous use for crude iron by the blacksmith all over eastern and northern India seems to suggest that the largest

supply of the metal came from Bengal. Since Bengal did not have any other source of iron, the entire supply must have come form the *Loha-mahal* region.[34] The blacksmith all over northern India liked this metal for its malleability. How old was the north Indian blacksmith's dependence on the so-called *Bangla Loha* can not be stated with any amount of certainty. Based on eighteenth century evidence, however, we can have an idea of the nature of trade in iron produced here.

In 1708, Alexander Hamilton found 'plentiful supply of iron' in the markets of eastern India.[35] Small iron markets were scattered throughout the entire *Loha-mahal* region, sending iron in *banjara* cattle and river borne to different parts of north India. In the west, Munger was an important centre of this trade, explaining the localisation of its gun-making industry. A similar centre in the east was Birbhum, receiving its supplies of iron from small and sundry *aurangs* in its vicinity supplemented by its local production. Early nineteenth century evidence also refers to the existence of iron-merchants' colony in Birbhum, which had an extensive trade in iron. In the late eighteenth century, therefore, the amount of crude iron exported from Birbhum to one of the north Bengal districts thus appears to have amounted to more than six thousand maund per year.[36] The profitability of iron trade in Birbhum is also indicated by the existence of the system of leasing out land to iron merchants. In 1774, for example, one Indranarain Sharma failed to secure a seven-years' lease of the iron-producing Mallarpur pargana of Birbhum even by offering twenty six thousand rupees. Indranarain was a local person, his failure thus indicates the involvement of rich iron merchants in the deal, who must have come from outside.[37]

The present theme does not require a detail discussion of the nature and organisation of this trade, or the nature of merchant participation in the manufacturing of iron. This extensive trade, as it appears in the eighteenth century, must have been however the result of a long drawn evolution of its market demand. The antiquity of the *Loha-mahal's* association with the metallurgical activities has been indicated above. Since the late medieval period,

increasing political interference of various kinds led to its gradual integration with the rest of northern India; its strategic location as the gateway to eastern India had only accelerated this process.

In the context of the internecine warfare in northern India almost continuously from the early sixteenth century, the growing importance of this region as the monopoly source of iron was also not unlikely. The demand for iron must have also increased as a result of the Mughal activities of urbanisation and the increasing tendency of retooling agriculture with iron, also noticeable from this period. In the concluding part of this essay, I would try to explain the possible impact of this demand expansion on the technique of iron manufacturing in this region.

v) Extension of the workgroup

One logical outcome of the expanding demand for the blacksmith's craft was an expansion of the traditional workgroup engaged in this activity. What happened to the *Mundas,* as discussed earlier, must have also happened to similar other tribal groups of this region. The late eighteenth century evidence, therefore, frequently refers to numerous tribal blacksmith groups like the *Kols, Cheerus, Kherias, Hos* and *Bhooktas* working at the various levels of the organisation of this craft. By the late eighteenth century, the inward mobility of these tribal workers into the traditional *Asur* craft had virtually reduced the latter group to a microscopic minority.

However, the expansion of the traditional blacksmith craft within the tribal society of the *Loha-mahal* could not very much affect the existing craft technique; because most of them worked in the same eco-cultural environment; the social motivation of their craft also remained the same. But this was not true of the blacksmith groups coming to *Loha-mahal* from outside. They had accompanied their masters, mostly iron merchants, a few of them were right holders also. These blacksmiths had introduced important changes in the traditional craft of iron smelting in this region.

The blacksmith's migration from different parts of northern and eastern India into this region must have been taking place over a long period of time. Initially, such migration might have been seasonal, accompanying iron-merchant's regular trip to the *Loha-mahal* during the busy months of iron smelting *-Aswin to Aghran*-according to the *Kol* calendar.[38] Later, some of these migratory blacksmiths must have settled here and freely interacted with the local blacksmith population. In view of the growing demand for iron, the blacksmith's migration into this region was nothing unusual. The iron merchants in their own interest must have also encouraged such migration; because it was easier for them to deal with craftsmen brought from their localities and using their own dialect.

The merchants had a compulsion also. With the increasing volume of this trade as indicated above, the refining of crude iron close to its smelting site became all the more necessary. Because, refining used to reduce the weight of the crude iron by a third, thus facilitating its transport — a great advantage in those days given the nature of transport used and the volume of trade involved. The abundant supply of cheap fuel in *Loha-mahal* had been an added advantage for the localisation of different branches of iron working. One, therefore, does not fail to understand the logic behind the migration of different blacksmith groups into this region. But, we would not depend on logic alone. A mid-nineteenth century survey stated that the Santal Parganas had a large contingent of migrant blacksmiths divided into three groups (*gain* or *ghar)* according to their place of origin. Thus when in the nineteenth century, a Palamou blacksmith claimed himself as belonging to the *Shergharia ghar,* what he suggested was that someone of his distant predecessors had originally come from Burdwan.[39]

Similar other groups of different origin also settled in other parts of this region. The migrant blacksmiths had brought about important changes in the traditional tribal iron-smelting activities of the *Loha-mahal.* They had brought with them their own perception of the craft and had a craft-culture of their own, quite

distinct from that of the primitive blacksmith. Because of their origin outside the *Loha-mahal,* they were also more informed of the nature and organisation of the market. Their close relationship with iron merchants also helped them. All these had enabled them to introduce important changes in the technique of production. I would refer to here only two of these changes—the improved furnace and the bellow—by way of illustration.

vi) Change in the craft-technique

Two types of furnace have been referred to earlier : the unorganised open-air furnace and small furnace or the *Saal.* In fact, nothing is known about the former, used primarily by the primitive blacksmiths. The latter was an improved version of the former, innovated by the *Munda Baraes,* capable of producing four to five seers of the metal in a single smelting operation of three to four hours' duration. Unlike the open-air furnace of the primitive smith, these could be used repeatedly necessitating a reasonable time gap and a minor repair after each smelting operation. Even in the late nineteenth century, these were the most numerous of the iron-smelting furnaces used in the *Loha-mahal* region. However, its existence at the lower rung of the particular industrial organisation indicates its close association with the village-based domestic system of production and craft culture of the tribal blacksmith.

The eighteenth century evidence refers to yet another type of the furnace, distinguished from others by its size and shape. It would have been much easier to explain this difference if we could state the relative measurement figures of these furnaces. But it is difficult to do so since accurate statistical data are not always available. In most cases, however, these furnaces were distinguished by their larger size, usable at a stretch for a longer period and capable of higher volume of production per smelting operation. In the perception of the local blacksmiths, these furnaces were known as the *Koth-saal,* hence different from the ones they were traditionally familiar with. In the local dialect, the term *kot/koth/kotha/kuthi* means a well-built house. The suffixing of *saal* with any of these terms thus indicates that the

saal or furnace was located in a similar structure. This is a significant deviation from the usual practice and as such indicative of the relatively higher usefulness and capital involvement of the furnace in reference.

Significantly, while the *saal* in evidence is always mentioned in terms of one or two tribal blacksmiths indicating its domestic organisation; the *Koth-saal* is invariably referred to in connection with the important iron-manufacturing centres or *aurangs* of the *Loha-mahal.* Deocha in Birbhum was one such centre, which in the early nineteenth century had as many as seventy furnaces of this type. Available indications suggest that these furnaces were of different capacities. Early nineteenth century evidence thus refers to one of these furnaces as capable of producing fifteen to twenty seer of iron per smelting operation of nearly eighteen hours at a stretch.[40] In 1850, Thomas Oldham visited Deocha and he stated that these furnaces had an average production capacity of 15cwt. of iron per week.[41] There are other references to larger furnaces capable of producing still a higher volume of iron. Because of their location far outside the region of our concern here I am excluding them from the present discussion.

I have discussed earlier that the *saal* type furnaces were linked to the domestic system of production, characterised by a combination of the mining, smelting and manufacturing of iron—all into one family unit. The women members of the blacksmith's family preformed the useful functions of collecting firewood and preparing iron ore cakes ready for smelting. The *Koth-saal* furnaces on the other hand were distinguished by a kind of division of labour, wherein each of these activities had been entrusted to separate workgroup. The existence of a distinct group even for the preparation of charcoal indicates the extensive nature of this specialisation. These workgroups were mutually interdependent through a market network with one or two iron merchants working as its fulcrum.

Another important feature of these furnaces was their constant use almost throughout the year, unlike other types of furnaces restricted to seasonal smelting of iron. It appears, therefore, the

Koth-saal furnace belonged to a higher level of industrial organisation system of production not only dependent on merchant capital but also having a direct participation of merchants. In the case of the domestic system of production also, blacksmith sometimes received advances from the merchants, but the latter in no way interfered with the production process. The absence of any reference to the *Koth-saal* furnace in the myths and narratives of the local tribal blacksmith groups seems to indicate their association with a craft-culture external to the *Loha-mahal*, which also suggests that these furnaces were the handiwork of the migrant blacksmiths.

An improved furnace necessarily involved an improvement in the system of blowing it. The difficulty of supplying the necessary blast to the large *Koth-saal* furnace by using the traditional twin bellows was quite obvious. Initially, they must have tried to overcome this problem by integrating a number of such bellows, synchronising their actions nevertheless remained a major problem. The functional efficiency of the traditional twin bellows could not, therefore, be improved very much. The use of deerskin as its cover and the system of pedalling the bellows remained other major obstacles in the way. Not unnaturally, therefore, the migrant blacksmith associated with important iron *aurangs* pressed into their service an altogether different type of bellow known as *phukan*.

The design and shape of this furnace was completely different from the traditional twin bellows. These were of larger size, covered by cow or buffalo hides, which the blacksmith operated by pulling a handle in a sitting posture. This bellow had higher output efficiency, requiring much less labour input, compared to the twin bellows of the local blacksmith. Unlike the later, this could be permanently fixed to the furnace, while integrating more than one bellows was relatively much easier here.

Other than its size, this type of furnace resembles close similarity with the one widely used in the late nineteenth century western India. In view of the long-term migration of blacksmiths from different parts of northern and eastern India to the region of

our discussion, this does not seem unusual. The expanding demand for iron working in this region had induced further improvement in the technique of this West Indian bellow. One could notice similar other evidence of improvement in tool techniques at the higher level of industrial organisation, compared to the technique applied at its lower level. However, one would always find it difficult to demonstrate such changes.

Conclusion

The foregoing discussion is based on just one aspect of artisanal technology in India. It appears, therefore, even in a relatively little known area of craft activities in India, followed primarily by isolated tribal workgroups, craft technique did not remain stagnant. In the long-term perspective, however, the process of this change was certainly very slow and mostly isolated and erratic. It was also negligible compared to advances in metallurgical techniques attained in medieval Europe or contemporary China. But the point, which deserves our attention here, is not the quantum of change but the evidence of change itself and its obvious direction. The process of this change, largely a post-sixteenth to late seventeenth century phenomenon, also does not appear to be very slow. A detail analysis of the iron-working crafts practised in some other parts of India would have been more useful in demonstrating the direction of change in craft technique. But that is not possible here.

Iron manufacturing was a capital intensive industry. In the pre-colonial economy, the demand for this craft was essentially limited; the use of iron tools in Indian agriculture was also not very extensive compared to its use in other countries, largely because of the geo-climatic factors. Even under such circumstances, the foregoing discussion of the iron-smelting activities in an isolated region does not support the conventional notion of an unchanging Indian craft-technique. It is logical to argue, therefore, that in the case of consumer industry based on highly flexible demand structure the process of such change was much more extensive. One of the basic objectives of this paper is to suggest an alternative methodology for analysing the process

of change in Indian craft techniques. What I have tried to argue here is that we can not hope to understand this process of change in the conventional way of historical research. Explaining this process of transition in the broader perspective of Indian craft technique hopefully remains our future research programme.

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32. For details of these workshop see my 'From *Agaria to Lohar*.'

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III - 2

COLONIAL CONSTRAINTS AND TECHNOLOGY : MARGINALISED INDIAN ATTAINMENTS

AMITABHA GHOSH

I

Colonialism is one of the agencies which fostered a kind of cultural contact between India and the West, particularly Britain. The darker sides of this contact which found the conquerors as beneficiaries are well documented. We know how the products of the so called Industrial Revolution, primarly Steamboats and Railways not only denuded us economicaly by opening up the country but also strengthened the political cum military subjugation. But as we would see later "Industrial Revolution" was a potitical construct, a veil to legitimate imperialistic expansion. This had close parallel to the construct of Orientalism, the East and West divide. Where the East is said to be spiritually developed and West, scietifically or technologigally.[1]

Introduction of steam-powered looms in Britain is usually considered to be the main agency of destruction of Indian cotton and cotton goods manufacturing but we should remember that India-woven cotton cloth remained competitive with British-woven cloth well in to the first two or three decades of the nineteenth century, a time when the "Industrial Revolution" was

at its peak. It was not superior technology adopted by the British Government which seriously affected Indian handloom even before power-looms had ousted handlooms in Britain,[2]

Steamboats, Railways and Electric Telegraph were all later utilised for purposes beyond the original intention for facilitating, establishing or speeding up communication, both for material (coal and cotton) and information, communication for the sake of trade, commerce or mobilisation of the army. 'Diana' the first steampowered gunboat of Britain was originally launched by the efforts of the British tradesmen of Calcutta in 1823. The East India Company was not at all interested in promoting steam shipping because many of its directors had shares in sailing ships called 'Indiamen'. However, fitted with canons and rocket-throwers Diana proved her mettle and eased the tension in favour of steamships. From 1823 many locally built wooden boats were fitted with imported steam engines both at Calcutta and Bombay. Introduction of iron-hulled steamboats dealt a deathblow to Indian ship building industry. Till 1840's the Mazagaon dockyards near Bombay produced excellent 'Indiamen' which found service with even East India Company. The ship-building activities were a near monopoly with the Persi Wadias — the master builders.[3]

Introduction of Railways resulted in over reliance on surface transport at the cost of inland navigtation and consequently neglect of canals and rivers. More surprising was one of the side effects of the introduction of railways. William Willcocks was the first to diagnose in 1930 that Malaria spread as an epidemic in the wake of constructions of embankments for laying railroads as it seriously affected the eco-system.[4] This was certainly unintentional but still forms the argument why scientists, technologist and planners should have some understanding of the history of science and technology. However grand and ambitious be our objective in subjugating nature for the benefit of either a chosen few or the masses, one should be aware that nature's reaction to many human manipulations in the past have not been very kind. When motor cars were

introduced they were considered to be the most 'clean' vehicle because city streets would no longer be littered with droppings by carriage horses. But now after a passage of about hundred years we are scared by the menace of car exhausts.

There was another adverse effect of introduction of railways in India. Unlike other industrialising countries it did not lead to the generation of new incomes from unemployed sources since a large amount of total expenditure was remitted 'home' (thanks to the guaranteed system offered to the British investors). Most important, the railway development in India did not result in the expected development of capital goods industry and technological innovation in engineering although in England locomotive factories were called "universities of mechanical engineering".[5] In contrast, though traditional technicians, particularly the displaced gun-makers of Monghyr, formed the largest chunk of the skilled labour force of the newly founded first major railway workshop at Jamalpur, they did not have any scope to get themselves formally educated and could never transcend the technician level and emerge as modern engineers.[6]

It is time now to take a look at the early educational institutes in India. In 1818, the Hindu College was founded in Calcutta. Its curriculum, offered among others, lessons in Natural Philosophy (Physics, Chemistry and Mathematics), surveying and medicine. Over-emphasis in teaching the Indians modern science had ulterior intentions. This was intended to remind us that roots of India's plight lay in her backwardness in certain areas of *modern* science. However, teaching of surveying and medical science was directly related to the manpower shortage faced by the colonizers. The same reason was responsible for founding of the civil engineering colleges around mid-nineteenth century. They needed assistance of second grade Indian engineers or rather, overseers to supervise the constructions of public works for exploitation of India and for oiling the clogs and wheels of colonial machinery.[7]

Before we proceed further, it is necessary to record that what ever be the intention, there were a few Indians who made the most of the opportunity they had. In the field of medicine, Madhusudan Gupta, a traditional practioner of Ayurvedic medicine took interest in the anatomical excercises and to the consternation of orthodox Hindu community was the first Indian to perform human dissection. He was appointed a teacher in the Medical College, Calcutta but had to undergo the humiliation of sitting for a qualifying examination later, before his appointment was formalised. After Madhusudan, four more Indians by 1840's secured their place of honour among British physicians but they had their higher education in England.[8] In the field of applied science, Radhanath Sickdhar (as he spelt his title), a brilliant student of Hindu College was picked up for his talents in Mathematics by Colonel George Everest and was in the service of Trigonometrical Survey of India as the highest paid Indian in Government service before 1857. Till to-day we have no 'Swadeshi' historians to record his attainments. Instead in the quest of 'Swadeshi' we have undermined him by conferring him the title of 'The man who discovered Everest'. Nobody has searched the documents of the Survery of India, otherwise, it would bave been amply clear that Radhanath, though he had nothing to do with the popular imagination, did more than that as the heights of all distant peaks including Everest were measured after a mathematical method suggested by Radhanath in a letter to Waugh, the Surveryor General, who succeeded Everest. Waugh appreciated it and thereafter all distant peaks were measured according to Radhanath's formulations. While extolling the attainments Radhanath we should never forget another Indian contemporary of him, Syed Mohsin, who unlike Radhanath had no exposure to western education and even could not write English. None the less, to the end of his career, he was in the employment of Survey of India as the first Indian "Honourable Instrument Maker to the East India Company". Virtually he was the founder of the present day National Instruments in Calcutta. Everest had the rare instinct of picking up local talents and like Radhanath from Hindu College, he

also picked up an "uneducated" artisan from Arcot, named Mohsin.[9]

Coming back to the main critique of introducing western science for the "benefit" of Indians, we should also take note that Indian intellectuals like Rammohun Ray strongly recommended it. Evidently he was a prey to the "Orientalism" theory — a construction of East-West divide based upon the assumption of a spiritually developed Orient, outwitted in the modern age by scientifically and technologically developed Occident. Quite in agreement with Edward Said and Martin Bernal,[10] I would humbly address the problem from a different angle. We always bracket science and technology in the same breath. But the relationship between science and technology over space and time has never followed any fixed trajectory. It is absurd to make a generalisation even today that technology meekly follows his big Brother, Science's dictation. Examples of changing relationship between science and technology can fill as many pages as one is permited by his or her publisher. I would however restrict myself to only one, the most revelatory one, in the context of Industrial Revolution—the steam engine. Industrial Revolution in popular history orginates from the use of steam engines—stationary steam engines. In the hands of James Watt by 1820 it acquired the potential of substituting human, animal, or water power in running manufactories. The first large scale factories and mass manufacturing owed their origin to steam engines. What was the role of science in development of steam engine? Suffice it to say, decades later Carnot explained the scientific basis of how and to what extent heat can be transformed into mechanical energy and thereby he founded a new discipline of science — thermodynamics.

With this non-linear science-technology relationship we should also take a look at what was taking place in England when the conquerors were pressing hard to introduce science education in India in the early nineteenth century.

The premiere scientific institution, The Royal Society, even as late as 1820's was engaged mostly in studies which could at

its best be attributed to the elite's enchantment with doing something "Scientifically". If one takes a look at the life and work of Sir Joseph Bank, founder ofThe Royal Society, it would be apparent that beyond supporting botanical explorations and promoting navigational aids they had little to offer in terms of science to boost the interest of the Imperialism.[11]

In the western historiography of development of Science in India in the late nineteenth and early twentieth century a few Indians like J. C. Bose, P. C. Ray, Meghnad Saha and S. N. Bose et al. have been recognised. I shall not dwell upon what is well known. But neglected by the West and even our East are numerous so called 'mistry's, a very derogatory term for artisans in the cultural hierarchy. A few case studies of these marginalised persons form the core of my argument that not only British Imperialism but also the class conscious and stratified Indian Society was equally responsible for underrating the 'illiterate' *Biswakarmas* in favour of Western educated 'Babu' Engineers.

A word of caution before our probings begin. Though the case studies comprise of only Bengalis, it has not been dictated by my allegiance to any particular culture zone. It is sheer ignorance in my part to read any other Indian language than Bengali. Visvakarmas are scattered all over India but one must know the local language to read the contemporaty texts to rediscover and reassess their attainments — the success as well as their failure in the colonial context. The vehicular agency of English alone (particularly Government records) is miserably inadquate for such a task. A. K. Priolkar in his book *The Printing Press in India* quoted from Gujrati and Marathi sources to rescue from oblivion two pioneer Indian typemakers and founders — Ganapat Krishnaji and Javji Dadaji whose contributions are no less remarkable than Panchanan, Manohar and Krishnachandra of Srirampur fame. Krishnaji also constructed iron presses.

My paper aims at presenting sketches of some of the eminent Bengali technicians and engineers having no formal education. Their excellence provides a different kind of evidence to prove

that introduction of engineering education had nothing positive to do with the people with talent and skill.

In Britain, Industrial Revolution saw the emergence of the millwright from the tradition of village carpenters, blacksmiths and wheelwright. In fact, the millwright was the representative of the transitional stage from the traditional crafts to the modern engineer. Such giants as Watt, Travithick or the senior Stephenson and many others began their carrier as self-taught highly skilled artisans.[12]

A similar pattern, however reduced in scale be it, does emerge from a study of the Indian pioneers working in an atmosphere not at all congenial. But engineering education did in no way help the Indians as it did their counter-parts in England. In fact, the system of engineering education with the motif hinted at earlier, created a gulf of difference between the illiterate 'mistry' and the 'babu' engineer. While the mistry with the traditional skill was denied the education, the engineer sought a profession tailormade by the Raj and smugly got fitted into an employment slot. There was hardly any scope for creative application for the Indian engineer.

A few notable exceptions like Nilmony Mrtra, the first Bengali engineer with a degree, pursued their trade independently. We would also do well to remember that the premier college of engineering in Bengal established in 1856, turned out the first batches of mechanical and electrical engineers with full fledged degree as late as in 1932 and 1936 respectively,[13] which lie beyond the time-frame of this paper.

Goluk Chunder

Goluk Chunder, a Bengali blacksmith of Titagar, can be acclaimed as the first Indian engineer if we abide by the original significance of the work 'engineer'. Engineer was a post-James Watt connotation and literally meant one who builds or erects steam engines. And Goluk Chunder did build a steam engine in 1828.

The first self-contained industrial complex of Bengal, set up in Serampore by the famous trio of Carey, Marshman and Ward included a foundry for type making, printing presses and even a paper manufactory. Paper-making in Serampore started from 1809, but the real breakthrough came in 1820 with the introduction of steam power.[14] The 12 horse-power steam engine of Thwaites Hick and Rothwells imported from England was an object of wonder.[15]

George Smith, the biographer of William Carey observed : "The machine of fire as they called it, brought crowds of natives to the mission, whose curiosity fired the patience of the engineman imported to work it, while many a European who never had seen machinery driven by steam came to study and copy it."[16] It was no European but Goluk Chunder who did ultimately produce a prototype.

The Steam engine made by Goluk Chunder was put on display during the Annual Exhibition of the Agri-Horticultural Society held at the Town Hall of Calcutta in January, 1828. The curious flower of iron, amidst fruits, vegetables and a dairy cow of enormous yield was awarded a special prize.[17]

George Smith wrote : "In the Society's proceedings for 9th January 1828, we find this significant record : 'Resolved at the suggestion of the Rev. Dr. Carey, that permission be given to Goluk Chunder, a blacksmith of Titigurh, to exhibit a steam engine made by himself without the aid of any European artist." At the next meeting, when 109 malees or native gardeners competed at the annual exhibition of vegetables, the steam engine was submitted and pronounced "useful for irrigation of lands made upon the model of a large steam engine belonging to the missionaries at Serampor." A premium of Rs. 50 was presented to the ingenious blacksmith as encouragement to further exertions of his industry.[18]

Nothing more about the life and labours of Goluk Chunder is known. There is hardly any reason to believe that further research may unearth yet more laurels for Goluk Chunder. We

will do well to remember that the Serampore paper mill, which upto 1865 competed with English paper in Asian Market as the only centre for mechanised paper-making in India, was "Gradually crushed by the expensive and unsatisfactory contracts made at home by India Office."[19]

Shiv Chunder Nundy

In the age of Industrial Revolution to cope with the ever increasing need to speed up communication abreast of steamships and railways, the new science of electricity found the first practical and large scale application in telegraph. It was with the introduction of electric telegraph in India as in Britain that the profession of electrical engineering came into existence.[20] The first Indian electrical engineer Shiv Chunder Nundy came from the field of electric telegraph.

In 1846, Nundy at the age of 22 joined the Refinery Department of Calcutta Mint. His technical aptitude came to the notice of O'Shaughnessy, the chemical examiner of the Mint and Nundy in no time became his personal assistant, the two of them together carrying out experiments in the laboratory.[21]

William Brooke O'Shaughnessy, Doctor of Medicine from Edinburgh, was a Renaissance figure who joined the Medical College of Calcutta as its first professor of chemistry and materia medica around 1835. He led a dynamic life of many activities as chemical examiner and Master of the Mint, as Joint Secretary of the Asiatic Society and finally as the father of the electric telegraph in India. A series of articles published in the Journal of the Asiatic Society of Bengal and a few books and pamphlets authored by him bear ample evidence to the numerous experimets of diverse natures conducted by him in the field of electricity.

He utilized an accumulator of his own design in 1829 to explode a charge of gunpowder under water for blasting away a ship named 'Equitable' which sank near Faltah Sands and was obstructing the passage of other vessels.[22]

In 1839, the first experimental telegraph line was successfully tried in the Botanical Gardens but O'Shaughnessy had to wait for ten more years before obtaining the approval of the Directors of the East Indian Company. In 1851, work for the 21 miles long first section was completed. A portion of the line which ran underground was unearthed during the course of some excavation carried out by the Bengal Telephone Corporation in 1827,[23] A severed metre or so of this cable can be seen in a gallery of Birla Industrial & Technological Museum, Calcutta. This cable also invokes the memory of Shiv Chunder Nundy. It was Nundy who sent the inaugural message from Diamond Harbour in 1851 and it was received at Calcutta in the presence of Lord Dalhousie and O'Shaughnessy.[24]

Immediately afterwards, Nundy, the first Indian in the Telegraph Department, was entrusted with the instruction and training of other signallers. Nundy did yeoman's service to Telegraph Department as in-charge of construction of about 900 miles of line linking East Barrackpore with Allahabad, Benares with Mirzapur, Mirzapur with Seonee and Calcutta with Dacca. During the construction of the Calcutta-Dacca line, it became necessary to lay 7 miles of underwater cable to cross the river Padma. With no steamer company willing to lend their vessels for the work at less that ten thousand rupees, an exasperated Nundy got it done by hiring country fishing boats. Hemendra Prasad Ghosh's tribute to Nundy published in 'Basaumati' contains many details about the life and heroic deeds of this man.[25]

There are some beautifully executed coloured lithographic reproduction of the drawing of telegraph posts, innovated by Nundy, in the possession of National Archives, Delhi. These drawings, along with an accompanying letter which he sent to O'Shaughnessy on 30th September 1855,[26] are sufficient to secure for Nundy the distinction of an engineer proper, one, who in his ability to make creative application can only distinguish himself from the repetitive pursuits of a mechanic.

The year in which Nundy wrote the letter, also saw the publication of the first treatise of the electric telegraph in Bengali by Kalidas Moitra of Serampore. Though the English sub-title humbly offered it as 'The telegraph office assistants manual', there is little doubt that the author had first hand knowledge about the progress of work in India. Moitra even put forward his proposal for sending messages in Bengali. The book contains a chart illustrating the Bengali keyboard as an alternative arrangement.[27]

Kalidas Seal

Skipping some intervening years the story is resumed from the age of electric generation by dynamo machine. Contrary to general belief, electricity for the purpose of lighting came to Calcutta at least twenty years before the first electric generator of the Calcutta Electric Supply Corporation was turned on in 1899. In the pre-CESE days, electric lamps meant carbon arc lamps. They were rather formidable. ("The hissing noise of the electric light in a quiet room is simply unbearable")[28] To maintain a constant gap between the eroding tips of the two arc-forming carbon rods, many kinds of regulators were designed. The regulators mostly depended upon movements controlled by automatically produced electromagnetic actions as the distance between the carbons changed. All the major manufacturers of arc lamps, Serrin, Siemens, Brush and Edison etc. produced more than one form of regulators. Siemens for instance patented at least eight of them.[29]

The Statesman on 30 January 1885 and on 1 February 1885 observed a novelty in the form of electric light which was employed by a marriage procession at night. The light used in the procession in Chitpore Road, a "Serrin" 1500 candle-power, was "very powerful, brilliant and steady, and the illumination was so successful that a man could see distinctly objects at considerable distances." The newpaper did not forget to mention that "the electrician who arranged the apparatus is a rising young member of Scientific Bengal, Mr. Sil, of the firm of Dey, Sil & Co." On 5 February, 1888, the same paper reported that the

firm had applied electric lighting "to the *chotoordollah* (nupital car) of a marriage procession, on the occasion of the nuptials of one of the Mullick family at Pathuriaghata". Advertising as "Electricians, Electro-metallurgists and Brass Founders", they were located at 36, Wellington Street.

The same firm made their presence felt at the evening party given by the Indian Club on 28 December 1886 in honour of the delegates of the Second National Congress held at Calcutta. Among the guests was Rabindranath Tagore, who "very kindly sang a few excellent songs of his own compositon assisted by a strong chorus." Dey, Sil & Co., on the occasion illuminated the place with electric light and also exhibited electric aparatus of their own manufacture which were much admired by Father Lafont and Mr. Elliot, Professor of Physical Science, Presidency College.[30]

As part of the Jubilee rejoicings of Queen Victoria, when Calcutta was illuminated on 17 February 1887, the residence of the Maharaja of Durbhanga was lit by electricity by the same firm. It is interesting to note the even Governor's House was not lit by electricity at the time.

At the Annual Conversazione of the Mahomadan Literary Society held in the Town Hall on 27 January 1888, the Company exhihited carriage electric lamps, lighted by "Stored currents from accumulators" of their own make. They also exhibited sewing machines and table fans worked by electromotors, which were highly admired and Lord Dufferin "had a conversation with the manufacturer, and congratulated him on his ingenuity".[32]

The firm was in existence even in 1912. But it was shifted to the residence of its managing proprietor, Kalidas Seal at 6 Sagar Dhur Lane.[33]

Rajakrishna Karmakar

The next luminary in this 'House of Unknown Fame' is Capt. Rajakrishna Karmakar. Let me admit at the first opportunity that all my information is borrowed from a single source, ***Banger***

Bahire Bangali by Jnanendramohan Das, a stupendous mine of informations about eminent immigrant Bengalis.[34]

Rajakrishna was still alive when Jnanendramohan's work was published in 1915 and it is obvious that the author was either in direct communication with him or had access to first hand information.

Rajakrishna was born in 1828 in Dafarpur of Howrah. His father Madhav Chandra, a village blacksmith could not even sustain his son's school education. Rajakrishna as a lad of 14 years, found the first admirer in his employer, the engineer-cum-manager of Ganges Company of Howarah, who sent him on many errands requiring ingenuity. He next found employment with Government Surveying and Mathematical Instrument Department, where he was engaged in fabricating surveying instruments like theodolites. He left his new job with East Indian Railway Locomotive Department to found a flour mill at Salkea. With the failure of the mill, he subsequently found employment one after another in Calcutta Mint, Water works at Palta, Jute Mill of Ghusuri and Bally Paper Mill. With the object of learning gun and ammunition making he first joined Govt. Gun Foundry at Cossipore and then Government Cartridge & Bullet factory at Dumdum as the head mechanic.

In 1869, at a monthly salary of Rs. 150 he joined the service of the Government of Nepal and left for that country accompanied by five assistants — Shyamacharan Karmakar, Digamber Chandra Laskar, Girish Chandra Kansari, Kailash Chandra Ghosh and Jadunath Nundy. His first job with the Mint saw introduction of machine forged coins in Nepal. On his transfer to the ammunition factory, he set up a water-wheel to provide motive power for the manufacturing processes. A few years after the death of Maharaja Chandra Samser Jung, he came back to India in 1880.

After trying his hand at independent business and various small jobs, he went to Kabool with 12 mechanics at a monthly salary of 200 rupees. A few miles away from Kabul in a place called Badurbagh, he set up three ammunition factories within

a span of six months. The machineries for these gun and ammunition factories were obtained from Walter Locke & Co. For the benefit of the Ameer of Kabul, Rajakrishna laid a small railway line from the Durbar to that factory and a five horse power engine was employed for locomotion.

After the expiry of a two and a half years' contract Rajakrishna on his return found a fresh invitation from Maharaja Vir Samser Jung of nepal. He left for Nepal in 1884 with two of his Kabul companions, Jadunath Nundy and Adharchandra Karmakar. The new gun factory and wood-working works set up by him earned him the title of Captain and a valuable and ornamental decoration in the form of a 'pugri'. Of all the foreigners employed in Nepal, he was the first to be conferred with a regular title by the Nepal Goverment.

After working for two years, he enjoyed a leave of two months and on his return lit the first electric lights of Nepal. Jnanendramohan observed that at the time of his writing (around 1915) the dynamo installed by Rajakrishna was still in existence in a dilapidated condition in the palace of the Maharaja. He also succeeded in manufacture of machine guns and after his retirement settled in Nepal at a place near Baghmati river.

Upendrakisore Ray

As a writer, illustrator, painter and even as a musician, Upendrakisore needs no introduction for the Bengalis. But in the West, Upendrakisore in his own life-time won acclaim as a first ranking scientific worker who brought mathematical precision to the process camera work, which in our popular parlance has taken the form of 'inventor of the half-tone block'. He certainly did not introduce half-tone blockmaking in India let alone its invention. But this revelation similar to the debunking of the Apple-Newton myth does not find the genius poor even by a shade.

In 1895, Upendrakisore, a self-taught man, founded his firm of half-tone blockmaking and bromide enlargements.[35] In the course of time, U. Ray & sons emerged also as printing house

of distinction.[36] 'Sandesh', the proverbial magazine for the children in Bengali founded by Upendrakisore could also be considered as the house journal of the firm for illustrating their skill and ingenuity.[37]

Between 1897 and 1911-12, Upendrakisore contributed nine research articles for Penrose's Pictorial Annual published from England and considered to be the printers' Bible of the time. Process camera differs from an ordinary camera primarily on account of incorporation of a screen with opaque rulings which breaks up the original picture into a conglomeration of dots in the negative. Upendrakisore made use of diffraction, a little understood phenomenon of physics, to obtain half-tone negatives. Understanding of the diffraction principle also first enabled him to make direct half-tone negatives of three dimensional objects.[38]

Upendrakisore also invented an equipment for automatic adjustment of the screen in the process camera. It was used to be sold as an attachment of the process cameras of Penrose-make.[39]

Upendrakisore was the first to point out theoretically two completely different kinds of screens, namely, a sixty degree screen and a three line screen. One Mr. Schulze got one such 60^0 screen made after the publication of the relevant paper by Ray and took a patent for it. The Penrose editor, Mr. Gamble, a great admirer of the 'classical pen' of Ray, admitted "Mr. Ray is able to prove that he anticipated by some years the 60^0 screen ....".[40] Upendrakisore, referring to this unethical act, in his subsequent article in the Penrose made a memorable comment: "to the craft it matters little who gets the credit for a particular invention. What directly concerns them is the addition of a valuable resource to their equipment."[41]

Introduction of Multiple Diaphrams was another major contribution by Ray. In process-work multiple exposures are sometimes given to the same negative using different aperture and speeds. The apertures differed in size only, the shape being

the same, circular. Upendrakisore mathematically determined how an aperture plate with multiple perforations of different shapes and sizes could be made, so that one exposure could suffice.[42] He made the process camera work like an ordinary camera in the sense that a single pressing of the shutter was enough for securing the image.

The firm of U. Ray & Sons were the originator of the chain reaction which led to half-tone blockmaking in Calcutta taking the shape of a cottage industry. The wood-blockmakers thrown out of their trade with the advent of half-tone were soon found to be outnumbered by the half-tone workers.[43]

H. Bose

Hemendramohan Bose, better known as H. Bose, was the first commercially successful manufacturing perfumer of India. Kuntalin, a hair oil, the perfume Delkhos, many kinds of fruit syrups, and hair wash — all of his products won a big market. Tambulin in a way was years ahead of the present Pan-parag class.[44] Bose was also the first to turn out indigenous voice recordings on a commercial scale in India. He founded the phonographic business in 1905. 'The Talking Machine Hall', as it was named, was situated in Marble House at 41, Dharmatala Street.[45]

In early 1906, at the peak of the anti-partition agitition in Bengal, the first batch of phonographic records, the so-called cylinder records were offered for sale.[46] Labelled as H. Bose's Records, all of them were patriotic songs and sung by none other than Rabindranath Tagore, Dwijendralal Roy and Kaliprasanna Kabyabisarad. No less than sixteen songs of Rabindranath including such all time favourites like 'Sarthak Janama Amar', 'Ebar tor mara gange', 'O amar deser mati' or 'Aji Bangla deser hriday hote' were issued as H. Bose's Records.

In the Indian Industrial Exbibition of Calcutta held in 1906, H. Bose's phonographic record was awarded a gold medal on the recommendation of Professor Jagadis Chandra Bose, the official judge.[47]

With the advent of the disc record, H. Bose felt the necessity of switching over from the cumbersome cylinders. He got into a partnership with the famous French firm of 'Pathe' and got many of his cylinders transferred into discs bearing the lable, Pathe-H. Bose's Record.[48] One such record, containing the recitation of 'Sonar Tari' on one side and the song 'Bande Mataram' on the other is the oldest existing voice recording of Rabindranath Tagore. It is worth nothing that after the H. Bose connection, Tagore did no more recordings for almost 15 years. His first recording with Gramophone Company coincided with the introduction of the electrical amplification system.

Prasanna Kumar Ghosh and Bepin Behari Das

'Sulabh Samachar', a Bengali periodical, in 1871 noted that about two years ago a kind of two and three wheeled cars arrived in Calcutta which could be propelled by gesticulation of legs, obviously meaning, pedalling.[49] It is also on record that around 1867-68, the Maharaja of Burdwan imported a velocipede.[50] But more important and astonishing too is the following report which was published in the above-mentioned paper a year before, "Many of us must have seen that there is a kind of three-wheeled vehicle in Calcutta which is not drawn by horses. The rider himself is required to exert pressure by his legs and that makes it run faster than a horse-carriage. Recently, a blacksmith of Santragachi according to his own idea prepared a vehicle of similar kind. In this vehicle one person at the front and two at the rear make the wheels rotate by their legs and the vehicle moves on its own."[51]

Obviously, the report was referring to a cycle which is technically known as the tandem type. A few weeks later 'Sulabh Samachar' further added that a man named Prasanna Kumar Ghosh was its manufacturer.[52] This is all that we know about the first Indian manufacturer of a cycle.

When motor cars started to make their presence felt at the turn of the century, the famous coach-builders of the day like Steuart & Co. or Dykes & Co. of Calcutta found little difficulty

in reorienting their expertise and built elegant car bodies. In the 1920's Russa Engineering Co. produced light Russa cars with Ford engines.[53]

The first motor car built in its entirety by an Indian was named 'Swadeshi' by its designer and manufacturer Bepin Behari Das. Bepin Behari, a self-taught mechanic working in a small shed near Ballygunge Police station (Ballygange-Bondel Road crossing) built all the components of the cars including its body and chasis except for tyres, spark plugs, carburettor and magneto. 'Swadeshi' was a 15 hp L-head 4 cylinder 5 seater and 4 door touring model car.[54]

Das sold his first car to Benares Hindu University in 1931. D. P. Khaitan, a councillor in Calcutta Corporation noted in 1932 that the car was still on the road, had already run for more than two years and was used by Pandit Motilal Nehru and Pandit Madan Mohan Malaviya.[55]

Calcutta Corporation entrusted Das the task of building a second car for them at a cost of Rs. 3000/-. Arrangement were made to pay him Rs. 300/- per month as advance for six months. It is interesting to note that when the delivery of the car was a little delayed almost all the councillors expressed serious doubts regarding the capability of Das and were certain of misuse of public money. Among the doubtful were Hon'ble B. K. Basu, Sushil Ch. Sen, F. Rooney, Bhupendranath Banerjee, Khan Bahadur Abdul Momin, P. N. Guha and Prof. S. C. Ghosh. Das was supported in his venture by the mayor Santosh Kr. Basu, D. P. Khaitan, N. C. Paul, Chairman of the Works Standing Committee and J. C. Gupta, Motor Vehicle Superintendent of the Corporation.[56]

After the first trial run of the 'Swadeshi' in Calcutta in November 1933, the motoring editor of 'Advance' wrote, 'last week an event, which will perhaps stand out as epoch-making in Indian Industrial history, took place, comparatively quietly when the first motor car manufactured in Bengal by a Bengali, was passed by the police for registration and awarded the number

35977. "The car did upto 35 mph and the ease in steering and its good acceleration were praised by the correspondent".[57]

But Das's endeavour found little appreciation and no financial backing. He built another car for Gwalior State which ran satisfactorily for many years. He was engaged upon another venture in Calcutta at the time of his death in 1938. He was only 55. A perfunctory obituary in the Municipal Gazette concludes with the comment : 'He was undoubtedly justified in his claim to have been the only Indian manufacturer of a car in this country'.[58]

Nilmony Mitra

The tercentenary celebration of Calcutta have unfortunately taken the shape of simply harping on an all-British tune. There is no wonder that it is the European buildings which have kept the painters and photographers equally busy while scholars are engaged in deciphering the styles of architecture — the diminutive Gothic, Roman, Doric, Palladian etc. But unnoticed, in this city of palaces still exist a few nineteenth century edifices which speak eloquently for their architect, Nilmony Mitra, who in spite of his English schooling borrowed heavily from the Indian heritage to produce a Hindu-Muslim mix.

It is worth quoting in full the obituary published in the Indian Mirror after his death on 24 August, 1894, at the age of 69, "During his college career, his extraordinary attainment in Mathematics, induced the Rev, Dr. Duff to exert all his influence with Sir Henry Lawrence, the then Lieutenant Governor of the North-Western Provinces, to allow this first Bengali gentleman to enter Thomason Civil Engineering College in 1851 at Rurki, and he more than justified Dr. Duff's expectations by heading the list in every examination and carrying off all the highest prizes. Specially recommended by Major Oldfield, the then Principal, he joined the public service at Calcutta and after five or six years of distinguished career, he retired from the service, determined, as he said, to open out an independent line for men of his profession in Bengal, and he succeeded. Simple and

unostentatious, strong in his principles and an upright and conscientious man, loved and respected by all, he rose to be one of the most distinguished men of Calcutta. He was an authority in his line, and was often consulted not only by Municipal Corporations, but sometimes by Government officials. He had an unparalleled genius for Indian architecture, and devoted his life to its development, and many noble buildings, in and out of Calcutta, are his living monuments. Thus, through his exertion and personal sacrifices, Madhupur has risen to be the beautiful sanatorium it now is. Besides his professional duties, he had to discharge others, no less arduous, as a respected citizen; and he discharged them all, conscientiously and to the satisfaction of all. He was a fellow of the Calcutta University, and Honorary Magistrate of the 24 Parganas and of Dum dum and also for some years a Commissioner of the Calcutta Corporation."[59]

The impressive list of Mitra's creations includes Pashupati Bose's house in Baghbazar, renovation of the 'Belgachia Villa' along with the addition of a zenana Mahal, Belgachia School building, house of Metropolitan Institution established by Vidyasagar, the first building of the Cultivation of Science at Bowbazar Street, Kirti Chandra Mitra's house in Mohanbagan, the palace of Jatindramohan Tagore and 'Emerald Bower', the Ratan Lodge at Chandernagor and the Narendranath Dutta Memorial Bathing Ghat at Panihati. The famous iron chariot of Mahesh was also built according to his design.The plan for the Sadharan Brahmo Samaj Temple was also drawn by him though he never embraced Brahmoism. He was the first to build public bathing houses for ladies and gentlemen of Calcutta at Shyam Square in 1883.[60] 'Battala' was the first house built by him in 1888 in Madhupur. Subsequently he built 'Kantaltala' and a few more which are remarkable for their simplicity and functional designing.

On 26 January 1895, Alfred Croft, Vice-Chancellor of Calcutta University, in his convocation address paying homage to the deceased said, "To the residents of Calcutta, it may be

said *si monumentum requires, circumspice* (if you seek his monument look around you). The mansions of many of the wealthy inhabitants of Calcutta and other important buildings of public character, bear witness to the originality and success of his ideas".[61]

The descendants of Nilmony Mitra in their ancestral home are justly proud of an oil painting of their great grandfather. A compass is seen to be held by Mitra in the painting. The compass is also preserved with other components in a historical instrument box.

Conclusion

In conclusion, I would like to add that it would be wrong to assume that the few persons dealt with in this paper were the only examples of creative talent in the field of technology in Bengal. Panchanan, Manohar and Krishnachandra belonging to the three generations of the Karmakar family, the pioneer Bengali type makers and founders; Sitanath Ghosh, who taught the young Rabindranath Tagore physical science and manufacturer of an air pump and power loom exhibited in Hindu Mela in 1870;[62] Mahendranath Nundy, ridiculed by Rabindranath as an unsuccessful match factory maker in Narayanganj, Dacca;[63] Devendranarayan Basak who ran an oil mill by steam in 1877;[64] Prankrishna Mukherjee, the inventor of a rope making machinery in 1884;[65] Kalicharan Basu, manufacturer of biscuit making machineries in 1885;[66] Jagadishwar Ghatak, inventor of water cycle boat in 1885[67], paddy husking mill[68] and punkah pulling machinery in 1895-96;[69] Pundit Kedarnath Chakraborty, inventor of the 'Easy Printer' who was granted a patent for it in 1901;[70] Ganadev Ganguly of Remington Co., manufacturer of a Bengali typewriter in 1906-07;[71] Banerjee & Co., builder of a steam launch in 1906;[72] R. K. Das, the maker of Bed-room fan in the same year;[73] and A. M. Dastur and C. C. Ghosh, makers of McCarthy type Gin (granted with U. K. Patent No. 13488, 1902)[74] — all of these inventors, innovators and manufacturers and many more require individual attention. Resurrecting the

biographical details of Malek, Jamshed, Barik and Putiram, the Indian technicians employed by Jagadis Chandra Bose, the great experimental physicist, to build his instruments, still remain to be undertaken.

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III - 3

SCIENCE AND NATIONALISM IN BENGAL (1876-1912)

CHITTABRATA PALIT

The nationalist stand on science in Bengal can only be understood if we correctly define the current expression in this area, colonial science. Most academics understand by it only the time-frame i.e. science that developed during the colonial period. Many include even the nationalist science activities and achievements as a product of colonial rule. George Basalla goes further to mean that colonial science is the arrival and acceptance of European science in the colonies, where there was not a semblance of science before European colonisation of India. It led to transfer of science and technology for the first time and its dissemination in the benighted country and its consequence was her material progress.[1] Both are unhappy explanations of colonial science and Basalla's Eurocentric view can not go unchallenged. It is common knowledge that ancient civilizations like India had a rich scientific past before the British conquered her and the tradition was not wholly lost though it was hegemonised by Imperial science. What happened in British India was not transfer of science and technology but transplantation of European science and technology. Colonial science was not, therefore, a matter of time-frame or periodisation of history. It meant much more than that. Colonial science in my opinion is accumulation of scientific knowledge

about the resources of the colony and utilisation of this knowledge for extraction of these resources for colonial purpose. In this sense, the Baconian dictum that 'knowledge is power' can be recorded.[2] Foucault more incisively makes this equation of knowledge with power and its control and manipulation for the benefit of the ruling class.[3]

Right from the beginning, the British authorities had no intention of imparting scientific education to Indians. The pursuit of science was confined to the Asiatic Society and the various survey offices. These were closed preserves of the Europeans and Indians had only a nominal participation as subalterns.[4] The Asiatic Society was the citadel of colonial science. It gathered all kinds of scientific information about India by painstaking researches done by the Company's British officials, based on information supplied by the Indian munshis and the pundits. This information was doubtlessly fed into the administration for colonial extraction. The survey offices served the same purpose. The land survey, botanical survey, geological survey, anthropological survey offices had qualified personnel in science but the information that they gathered was closely guarded for colonial use.[5] The knowledge was not for dissemination to the Indian public. This is the reason why at the time of Anglicist-Orientalist controversy; Rammohun wanted the sum of one lakh rupees allotated by the Company's Government for imparting scientific education to the Indians. In his letter to Lord Amherst in 1823, he clearly pointed out that India was already rich in philosophy and literature but deficient in the scientific knowledge of the West. He implored the Government to spend the sum on promotion of natural sciences in eduational institutions.[6] For this purpose scientific books had to be imported, laboratories had to be set up and qualified foreign teachers from abroad had to be appointed. But this appeal of Rammohun had fallen on deaf ears and ultimately in 1835, Macaulay settled the contest by having an Educational Minute passed in the council in favour of English education but mostly literary. In the Government colleges and schools the literary curriculum prevailed. Whatever science was

taught in the Hindu College was of an elementary nature.[7] Shivnath Shastri in his memoirs narrates how one Professor Tytler used to teach only the composition of soda in his Chemistry class and thereby was nicknamed 'Soda Sir'.[8] The Calcutta Medical College was the only academic institution where science was taught at a high level because medical students would have to deal with life and death questions of even white civilians.[9]

Dr. Mahendra Lal Sircar was born in 1833, the year of Rammohun's death and later destined to become the father of modern science in India was admitted to the Hindu College initially. But determined to pursue a science course, he left the Hindu College to join Calcutta Medical College for this purpose much to the surprise of his guardians and classmates who still thought that a literary English education was not only a bread — winner but also the most civilized form of education.[10]

This brings us to a study of the phenomenal career of Mahendralal who rose to become not only the top homoeopath of his time but also the father of Indian science. As we have already observed, he joined the Medical College where he could study science proper to his intense delight. He duly qualified for L.M.S. and in 1863 he was the second Indian M.D. from the College.[11] He set up his medical practice and became an active member of the Calcutta Chapter of the British Medical Association. In his initial years, he was a doughty champion of Allopathy and in one of the meetings of the association he denounced Homoeopathy as mere quackery.[12] At this stage he got Morgan's Philosophy of Homoeopathy for review in the *Indian Field.* On reading this work he got converted to Homoeopathy and wanted to know more about it. He became an apprentice with Dr. Rajendralal Datta, the legendary Homoeopath of Calcutta. The principles and practice of Homoeopathy convinced him of the efficacy of Homoeopathy as a cure.[13] He placed it above Allopathy in a seminar of the British Medical Association. It raised a hue and cry among the charmed circle of the leading Allopaths of the city, Ewert, Waller

and Surya Kumar Goodeve Chakravarty. They launched a tirade against him for his apostacy. He was declared to be a mad man and he was ostracised by the doctor community. Mahendralal began to lose his practice and was put to dire financial straits. Even his non-paying clients deserted him. But Mahendralal persevered. Those who had left him in favour of Allopathy began to return slowly. His practice looked up again. The dark period was over. He made such a name in Homoeopathy that his fame was little short of Dr. Rajendralal Datta.[15]

Mahendralal had not forgotten the conspiracy of the British doctors to ostracise him for his switching over to Homoeopathy. This had injured his freedom to pursue Homoeopathy as an alternative science. He considered it as a colonial constraint and since then contemplated the founding of a national science association which would be controlled and funded exclusively by the Indians themselves. The projected association would be dedicated to the cause of science in India for the purpose of national reconstruction.[16] Mahendralal started his campaign for the association from 1867 onwards. He published appeals in the *Hindu Patriot, Calcutta Medical Journal* etc. and issued pamphlets during his public lectures on this subject. Public opinion in favour of the project was fast building up.[17] But there was a crunch of funds. Mahendralal sent out appeals to Rajas, Maharajas, Zamindars and professional elites of India to contribute liberally to this noble cause. The response was overwhelming,. To this Mahendralal contributed his life's savings.[18]

Once this launching pad was ready, he appealed to the Bengal Government for support to the cause. But at this stage, he faced a stiff opposition from an unexpected quarter. The Indian League which had branched off from the British Indian Association as an organ of the professional landed middle class was seeking recognition from the Bengal Government. The Ghosh brothers, Motilal and Sisir who were the founders of the Indian League wanted to placate the British Government, particularly Lt. Governor Sir Richard Temple.[19] They came out with a rival

proposal of establishing a technical institue to be named after Prince Albert, consort of Queen Victoria who was then visiting India. The argument that they gave was that an institution for vacational education was more desirable to provide employment to poor and jobless people. A science association could wait as it was the territory of the privileged. The colonial Government would only be delighted if the national science association was thwarted by inner conflict of this sort. The Indian League Government alliance came to be popularly known as the Ghosh Temple League.[20] Both sides began to mobilise their support from the public. Ultimately, Temple sought to resolve these conflicts by holding a public meeting in the Town Hall. The historic meeting was held in 1876. Rev. Eugene Lafont of the St. Xaviers College, Keshab Chandra Sen and Rajendra Lal Mitra took the side of Dr. Mahendralal Sircar in this debate while Sambhu Chandra Mukherjee, the noted editor of Reis and Ryot and veteran Rev. Krishna Mohan Banerjee took the other side. The eloquence of Keshab Chandra and the arguments of Father Lafont and Rajendra Lal Mitra won the day for the National Science Association.[21] Lafont pointed out that the National Science Association was not exactly opposed to the programme of the technical institute. India needed a pool of scientists who would also act as trainers of the artisans at the technical institute. Otherwise they had to depend on foreign experts. Rajendra Lal Mitra supported Lafont on this score by saying that only a generation of Indian scientists could train our artisans to higher skill and innovation.[22] Mahendralal himself replied effectively by saying that India could produce able scientists if not Galileo, Newton, Herschel and the like. The House voted in favour of the association and Temple had to accept the verdict. It was decided by the Government that a house at 210 Bowbazar street would be alloted to the National Science Association on the security deposit of Rs. 50,000 out of the total fund of Rs. 70,000 to be raised by subscription by the association. Thus the historic Indian Association for the Cultivation of Science (IACS) was launched in 1876.[23]

Review of IACS : (Indian Association for the Cultivation of Science). The IACS was dedicated to the promotion of higher studies in science and popular science. Mahendralal had hoped that the IACS would one day become an advanced centre of scientific research like the Royal Institute in England. The IACS, therefore, was planned accordingly. Its purpose was to absorb the benefits of western sciences and be abreast with it. But he was also for the utilisation of the saving elements of traditional science in India. Both were necessary for national reconstruction. Mahendralal also arranged a series of popular lectures on various scientific subjects which were generally held in the evening with the help of lantern slides. The purpose of these lectures was to popularise science among the common people. They were a big draw for college students who used to throng the hall in large numbers. The IACS was nicknamed a private college of science for this reason. But its efficacy cannot be gainsaid.[24] It led to considerable popularisation of science and Mahendralal's hope to fight superstition with science was largely fulfilled. The lecture domonstrations also had a practical side and promoted vocational training. The IACS had a long record of involving all noted scientists of Bengal starting from Mahendralal himself, Father Lafont, J. C. Bose, P. C. Ray, Nilratan Sarkar, Asuthosh Mukherjee et al, who contributed to both higher and popular science. The objectives of creating a pool of Indian scientists was also achieved. Mahendralal in his deathbed testament had lamented that the IACS could not become like the Royal Institute because of lack of patronage from the Indian aristocracy. But this frustration has no basis. After his death, the IACS expanded its activities and went from strength to strength. During the era of C. V. Raman, Meghnad Saha and K. S. Krishnan in the 30s of this century, its prestige was no less than that of the Royal Institute. All three contributed significantly to higher science and Sir C. V. Raman went on to become the first Indian Nobel Laureate in science.[25] Now it has attained world wide recognition as an advanced centre of scientific research and a colony of well-established Indian scientists, who can train all apprentices in the principles of

modern science and technology. Indian dependence on foreign scientists has virtually been eliminated in the field of industrial recovery and reconstruction. Our society has been considerably scientised, though its contribution is still restricted to the urban sector.

The Dawn Society

The lead given by the IACS in the field of nationalist pursuit of science was carried forward by the Dawn Society founded by Satish Chandra Mukherjee in 1902. Satish Chandra was already famous as an educationist. A teacher of South Suburban School in Bhowanipore, he had already established the Bhagavat Chatushpathi in 1895 which undertook studies on religion and philosophy. Its purpose was to explore the cultural heritage of India. In 1897, he launched the Dawn Magazine in which he propagated his ideas of national education. It was Satish Chandra's firm conviction that to love one's country one had to know it thoroughly. He started a column entitled 'Indiana' in the Dawn Magazine carrying numerous articles on different aspects of Indian civilization. The Dawn Magazine was widely circulated in every educated household as a journal of high standard and taste. In its run between 1902-1906, the Dawn took up the cause of national education in view of the official assault on higher education. The Government sought to control the University Senate and Syndicate through official nomination and shrinking educational opportunities by disaffiliation of indigenous colleges. Satish Chandra criticised the syllabus of Calcutta University as "all-too-academic, all-too-literary, unscientific and unindustrial".[26] In 1902 the Dawn society was established in the premises of the Metropolitan College with a new teaching syllabus and schedule. The courses were divided between general and industrial/commercial. Most classes were like practical classes where students were encouraged to participate in group discussion and submit their notes taken from lectures for scrutiny by teachers.[27]

The Dawn Society had a definite syllabus in science and technology. It had the four-fold objectives of salvaging the

worthy elements of traditional science, absorbing the benefits of modern science, spreading science to masses and offering job-oriented technical education. In this sense it continued the tradition started by Mahendralal at the IACS. Along with teaching science and technology from lower to higher levels, the members of the Dawn society wrote profusely on scientific subjects in the columns of the Dawn maganize. From 1896 no less than 70 essays appeared in the Dawn on science, technology and allied subjects. Members of the Dawn Society comprising of eminent scientists of the day wrote these articles.[28] Satish Chandra himself was responsible for many editorials on scientific subjects.

The other important sector of the society's activities was the Industrial School run by it. It was like a technical institute where training was given by experts for various kinds of technical jobs of elementary level. This was a programme which Binoy Sarkar later called 'Mistrification'[29] in connection with the Bengal Technical Institute. The Dawn Society produced many fitters, jointers, welders, chemists and weavers at the Industrial school. The products of these trainees were also displayed and sold in exhibition and in shops in Burrabazar. The sale figures show that the industrial school performed well. It opened up job opportunities for the new generation. Thus the national science movement not only continued in the proceedings of the Dawn Society but it also served as a vital link between th IACS and the future National Council of Education which founded the Bengal Technical Institute and finally the College of Engineering and Technology. To that historical development, we turn next.[30]

The NCE (National Council of Education)

Bengal was partitioned in 1905 to divide and weaken the Bengali Bhadraloks who were taking leading part in the freedom movement in Bengal. It caused a consternation among the educated Bengalis and they decided on a political movement to annul the partition at all costs. The movement comprised of boycott, swadeshi and national education. The programme involved national education for swadeshi industrialisation. It

meant a curriculum of science and technology for national reconstruction. The Dawn Society had already started such a course. It got merged in the activities of the National Council of Education which was founded in 1906 by the nationalists for national education including science and technology. When Satish Chandra founded the Dawn Society, its purpose was to spread national education when the Government of Bengal was trying to shrink the opportunities created by educated Bengalis. The National Council of Education had to face the further problem of government intervention because of its swadeshi activities.[30] The government banned all kinds of nationalist activity including singing of national and patriotic songs in schools run by the Council. Faced with this kind of oppression, the NCE got determined to pursue its ideals of national education more vigorously.

Its programme of boycott and swadeshi led it to provide an alternative path of scientific and technical education for swadeshi industrialisation. For this purpose, along with the Bengal National College which taught general arts and science, it established the Bengal Technical Institute (BTI) which provided the first phase of technical education.[32] This has been described as the programme of bread and butter education or 'Mistrification' or the first phase of industrialisation by Binoy Kumar Sarkar. The fathers of NCE emphasised on nationalism as the main incentive for the alternative form of education. But those who joined the BTI would not mix politics with their education. Sir Tarak Nath Palit who had donated 10 lakhs and his residential house at 92, Upper Circular Road also thought that the colleges under NCE should not be branded as political hotbeds.[33]

As soon as the Bengal Partition was annulled in 1911, the nationalist euphoria also abated. Sir T. N. Palit withdrew his munificence and gave it to the Calcutta University which had Sir Asutosh Mukherjee as the new Vice-Chancellor appointed by the Government. Sir Asutosh did not abandon the nationalist path, but Calcutta University was not known to be a centre of

political agitation. At least the Bengal Government thought it to be a safe place and Sir Asutosh a sage steward. Sir Asutosh absorbed much of the programme of the national education of the NCE without giving offence to the Government.[34] The net result of this overtures was that the Bengal National College and the BTI come under fire. The BTI had to change its venue but it gained popularity amongst students who did not get any opportunity to have technical education under Calcutta University. By 1917 it began to draw more students than the Bengal National College which looked deserted since 1911. The BTI had a successful run down to 1928 and provided valuable vocational education to many who got settled in life. From after 1928, the NCE transformed it into the College of Engineering and Technology (CET) which became the second phase of technological and engineering education or in the words of Binoy Sarkar, "the phase of industrialisation in education".[35] It became a close rival of the B. E. College, Shibpur for its variety of engineering subjects offered like Mechanical Engineering and Chemical engineering. From then on it never looked back. It got illustrious teachers in place of those who had left for Calcutta University. They created a nationalist tradition from the generation of Hiralal Roy to Triguna Sen. Its alumni went on to become the architects of modern India. Many went abroad and settled there having name and fame. Many established swadeshi industries like the Bengal Lamp, Bengal Waterproof etc. Binoy Sarkar calls this phase "Modernisation"[36] Thus nationalism and science went hand in hand in creating a swadeshi base of industrialisation and a pool of indigenous scientists to run it. Calcutta University under Sir Asutosh in its Colleges of Science and Technology also performed well. But it still suffers from the trappings of colonial education whereas National Council of Education was imbued with a nationalist spirit till the time of its renaming as Jadavpur University in 1956. The nationalist spirit ebbed obviously after independence but it had already played its glorious innings in swadeshi reconstruction under the withering touch of colonial rule.

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III - 4

SOME PIONEERS OF MODERN INDIAN SCIENCE DURING THE LAST FEW DECADES OF BRITISH RULE

CHANDANA ROY CHOWDHURY

The presence of galaxy of outstanding Indian scientists during the last fifty or sixty years of British India glorified the history of Indian science to a large extent. The pioneering activities of Rammohan Roy, Mahendralal Sircar and Satish Chandra Mukherjee developed an infrastructure of modern science in the country, utilising national resources and talent. Rammohan was the first Indian who emphasized modern scientific education and appealed to the British government to promote the study of different branches of science, instead of setting up a Sanskrit college.[1] Foundation of Indian Association for the Cultivation of Science in 1876 by Mahendralal Sircar, The Dawn Society in 1902 by Satish Chandra Mukherjee, National Council of Education (NCE) in 1905 and ultimately, the University College of Science in 1915 by Sir Asutosh Mookerji accelerated the progress of Indian Science in the Country. It is noteworthy that almost all the glorious names of Indian Science, namely, C. V. Raman, P. C. Ray, D. M Bose, S. K. Mitra, S. N. Bose, J. C. Ghosh, J. N. Mukherjee, M. N. Saha and many others (excepting J. C. Bose) were associated with the University College of Science, Calcutta during some period of their lives.

It is relevant to mention here that the aforesaid scientists were not directly involved with the independence movement then current in the country, but there was no doubt they were imbued with national feelings. Their patriotic mind encouraged them to uplift themselves and their countrymen through modern scientific education and research, and thereby belong to the comity of the nation of the world. Moreover, in this way they could prove themselves that they were not inferior to anybody in the world. This firm determination helped them to reach the high goal of achievement they did. Most of these scientists did excellent research work in their respective fields which involved the shift of the existing paradigm to a new one. According to Thomas Kuhn's definition, such works can be said as 'Revolutionary Science'.

In the present paper, contributions of some of the eminent Indian Scientists will be discussed in brief.

Jagadis Chandra Bose (1857-1937)

The first world recognition was achieved by Sir Jagadis Chandra Bose before the foundation of the University College of Science. In fact, he himself was an evidence of independent pursuit of science and technology even under the decaying touch of colonialism. Being born in a respectable Brahmo family at Rarikhal, Jagadis Chandra was sent to a Calcutta School in 1869 from where he passed the Entrance Examination in 1875 from St. Xavier's School with a scholarship and entered St. Xavier's College where he was deeply influenced by Father Lafont. He passed B.A. Examination in science group in 1879 from the University of Calcutta and then went to England for studying medical science. Due to repeated attack of Kala-azar he could not continue medical course and joined the Christ College, Cambridge for studying Natural Science, where he got the leading men of science as his teachers, e.g., Michael Foster, Francis Balfour, Sidney Vines, Lord Rayleigh etc. All of them, especially Lord Rayleigh, influenced him much in his later life. It is evident in the following lines :

"After Father Lafont at St. Xaviers' College, Calcutta,It was Lord Rayleigh at Christ's College, Cambridge who contributed most towards making a scientist of him."[3]

In 1884, he became B.A. of the Cambridge University as well as B.Sc. of the London University. Next year, he joined the Presidency College, Calcutta as an Assistant Professor of Physics in spite of strong protest of Britishers of high rank. At that time, there was in vogue a very disgraceful rule for the Indians in the Educational Service, that the Indian teachers would get two-thirds of the salary enjoyed by their European colleagues. The latent nationalism in Jagadis Chandra, inherited from his Deputy Magistrate father,[4] broke out and he strongly protested this illogical discrimination non-violently by refusing his salary for long three years. Ultimately, the authority cooled down and decided to pay his dues for three years. This incidence at the beginning of his career proves that he possessed a nationalistic mind and a firm character. He retired from this college in 1915, but was afterwards connected with it as Emeritus Professor.

After joining the Presidency College, he was not involved seriously in research work, rather he was engaged in various scientific hobbies, such as voice-recording of his friends with Edison's phonograph, entertaining his friends with various types of discharge tubes, cathode ray tubes kept in his laboratory. But suddenly in 1894, he decided to dedicate himself in unveiling the mysteries of nature.[5] According to his nephew and famous scientist, D. M. Bose, he became influenced to produce electromagnetic wave of short wavelength after reading Oliver Lodge's paper on "Heinrich Hertz and his successors", published in Nature (1894) after Hertz's death. It is interesting to comment here that his involvement in serious research may be due to continuous encouragement from his wife, Abala Bose, who had a great influence on his social and intellectual life, and who wanted him to be a serious scientist.[6,7]

Hertz discovered electromagnetic wave of nearly 5m wavelength whereas Bose produced that of 25mm - 5 mm

wavelength using his indigenous apparatus made with the help of almost illiterate workmen. It is mentionworthy that he had not got any help in his outstanding research from the authority of the Presidency College. He got a 20 sq. ft. room as laboratory and had to spend his earned money for research. Moreover, he had to do research at night after the college hours. But nothing could deviate him from his dedication in research as he promised to serve his motherland by making the progress of science in the country. He himself wrote, "yet within two years the Presidency College succeeded to win great renown at all scientific centres. My mechanician whom I trained was able to construct instruments of such extreme delicacy that it was impossible to duplicate them in any part of the world."[8] In November 1894, he demonstrated his historical experiment with microwaves using his self-made emitter and receiver in the Presidency College. When he switched on his emitter kept in Prof. Ray's room, a pistol was fired by the wave in Prof. Pedlar's room just attached to Ray's room. Father Lafont stood in between the two rooms closing the connecting door. It was a landmark in the history of wireless communication. After a few months, he exhibited the same experiment in the Town Hall in the presence of Lt. Governor Sir William Mackenzie.

The radiowaves having 5 mm wavelength consist of frequencies 60×10^9 Hz of 60 GHz. At the time of the second world war, J. B. Van Vleck showed that waves of such high frequency cannot propagate through air very far, but are absorbed by the oxygen of the air. American Military force used these frequencies to communicate confidential news to their allies nearby. Today, the microwaves of these frequencies are the only medium of communication of the militaries all over the world. Another advantage is that the distance of communication can be controlled by controlling the power of the transmitter, which is utilized by many countries for local communication. Besides that, it is also being used in artificial satellites and cellular phones.

Bose performed many quasi-optical experiments like reflection, refraction, polarization, rotation of plane of

polarization etc. with his very simple but delicate apparatus mounted on an ordinary spectroscopic table. His first paper entitled "On the polarization of electric rays by double refraction crystals" was published in the Journal of the Asiatic Society in 1895.[9] Next year (1896), Bose measured the wavelength of electromagnetic radiation as 20 mm emitted by one of his radiators with the help of a reflecting metal strip concave grating. This work was the main part of his thesis for D.Sc. of the London University. It is hereby mentionworthy that the D.Sc. degree was conferred to him only on the talent of his thesis and at the discretion of the University he was exempted from further examination.[10]

Bose was an inventor of many delicate instruments. He modified his emitter by enclosing it by cylindrical or rectangular metal tube which was a precursor of waveguides. He also built a very sensitive detector(coherer), made of iron and mercury in 1898 for receiving microwaves. With a prototype of this coherer, Marconi made wireless communication across the Atlantic Ocean in 1901 and took its patent and later got the Nobel Prize. The actual discoverer remained behind the screen. He was least interested in taking the patent for his discovery. Later, he modified his coherer by employing many semi-conductor crystals. In 1901, he built a very powerful electric-ray detector using Galena (PbS). It was the first photovoltaic cell in the world, which he named as 'Tejometer'. He got the patent of this in 1904 due to untiring efforts of Sister Nivedita and Ms. Bull of America though he was dead against taking patents. The Galena detector is not only sensitive to microwaves but also from infra-red to violet ranges. Bose invented special type of antenna called 'Horn Antenna' for his emitter and detector, which is still now used all over the world in microwave and milliwave radios, even in radar systems.

In 1945, Profs. M. N. Saha and S. K. Mitra visited U.S.A. and noticed that in many laboratories, the radar personnel were trained in using apparatus very similar to those designed by Bose. Since 1900, Bose was gradually shifting from microwaves

to other phases of his scientific research. Actually, his attention was then concentrated on overlapping area of physics and biology. It was the most important period of his life and a new subject, 'Biophysics', originated from there. Bose observed that inorganic systems also have electric response to stimulations, which was then known to be the property of living system (defined by Waller) only. To establish his new thinking, he had to stay two years (1900-1902) in the Davy Faraday laboratory of the Royal Institution. During this period, he wrote the monograph: "Response in living and non-living". He was convinced that not only animals, but vegetable tissues and even inorganic materials produce electric response to any kind of stimulation (heat, electric shock, chemicals etc.). The intensity of electric response is maximum for animals, and minimum for inorganic materials. For plants the electrical response is intermediary. In his words : "Nowhere in the entire region of these response phenomena, inclusive of metals, plants and animals — do we detect any break of continuity — there is no necessity for the assumption of a vital force. They are on the contrary physico-chemical phenomena capable of physical enquiry as definite as any other inorganic regions."[11] In his book "Comparative Electrophysiology"[12], Bose tried to classify the response effects in living and non-living and he devised some inorganic models which exhibit similar response effects to some stimuli in metals as was observed in the animals as well as plants in response of the same stimulii. He also made some models to demonstrate the physical basis of memory of storing information. His biophysical models can be considered as a precursor to the modern discipline of Cybernetics. From 1907 to 1933, i.e. the major part of his life he concentrated on the study of the response phenomena in the plant kingdom.

Jagadis Chandra had an inborn aptitude in Biology. Unfortunately, Biology was then not included in B.A. syllabus. In Cambridge, he studied both the physical and biological sciences. After returning to Calcutta, he had to be a teacher in Physics as there was no teaching post in Biology. Hence, it was very natural for him to shift to the Biological Sciences gradually, though his career started with wonderful researches in physics.

On 30th November 1917, he founded the Bose Institute with munificent donations from Maharaja Manindra Chandra Nandy and others, and adorned the post of Director of his institute till his death. Advancement of Science and diffusion of knowledge was the main object of his institute. In its inception, it was the only centre for studying plant physiology. Later on, other subjects were also started involving Plant and Agricultural Chemistry, Experimental and Theoretical Physics, Anthropology.

Now the question is : Why did Jagadis Chandra, in spite of being such a genius, fail to form a school of physics (biophysics) like his contemporary chemist, Sir P. C. Ray? There was a pertinent reason behind this. Bose's attitude towards his junior workers was not quite genial. He considered them as assistants and would hardly discuss with them scientific matters.[13] Also, he was impatient, and did not like any criticism of his work. Even his colleague, P. C. Ray and his illustrious student S. N. Bose began to dislike him.[14] In fact, owing to this unwelcome attitude many of his students could not continue with him for long.

He was elected a Fellow of the Royal Society in 1920, the General President of Indian Science Congress in 1927, the corresponding member of Vienna Academy of Sciences in 1928.

Prafulla Chandra Ray (1861-1944)

Sir Prafulla Chandra Ray contemporary to J. C. Bose was a prominent personality in the field of chemistry. He was born in a respectable family of Khulna and had early schooling there. The family moved to Calcutta in 1870 where he got himself admitted to Albert School. He passed the Entrance Examination in 1878 from that school and joined the Metropolitan Institute (now known as Vidyasagar College). Prafulla Chandra inherited the attitude of rational thinking from his father, Harish Chandra Ray who was a very cultured man and had close contact with Iswar Chandra Vidyasagar, Kristo Das Pal, Jatindra Mohan Tagore, Digambar Mitra and others.[15] While studying in the

Metropolitan Institute, Prafulla Chandra used to visit Presidency College as an external student to attend the lectures on chemistry in the First Arts course and the lectures in both physics and chemistry in the Bachelor of Arts course and finally got interested in Chemistry especially from the lectures and class demonstrations by Sir Alexander Pedlar, the then Professor of Chemistry in the Presidency College. He took up B-course in B.A. with the intention of doing higher studies in chemistry. Notwithstanding that, he had a keen interest in literature and he won the Gilchrist Prize, for which the competitors must have knowledge in at least four languages. This prize enabled him to go to Edinburgh University in 1882 for higher studies. In 1885, he obtained the B.Sc. degree and in 1887, he got the D.Sc. degree of the Edinburgh University for his thesis entitled "A study of Isomorphous Mixtures and Molecular Combinations". He also obtained the Hope Prize Scholarship which enabled him to continue his work for another year. In 1888, he returned to Calcutta and tried to get an appointment in the Bengal Education Department. His family was then in tremendous financial crisis and the only shelter for him was his friend Dr. J. C. Bose and his wife.[16] At last he was appointed as Asst. Professor of chemistry at the Presidency College on a salary of Rs. 250/- p.m. and proved himself as an excellent teacher very soon. He used to inspire his students through the story of the struggle of the great scientists to devote themselves in the pursuit of science. Between 1897 and 1936, he published 142 research papers and notes in scientific journals. His first remarkable research which brought him world recognition was the isolation of mercurous nitrite[17] in 1896 which was published in the Journal of the Asiatic Society. Mercurous nitrite was obtained in the form of thin yellow crystals by the action of dilute nitric acid containing 13.14% of N_2O_3 on metallic mercury in the cold. The action of potassium cyanide on mercuric nitrite led to the preparation of mercuric hyponitrite. After that, he discovered a number of new nitrites. He prepared some double nitrites of mercury (II) with barium, calcium and lithium in which he observed the decrease in stability with the increasing atomic

weight of the metals (other than mercury). Next he prepared compounds of mercury (II) nitrite with alkyl and aryl amines which have the form $Hg(NO_2)_2\ RNH_2$. During 1911-13, Ray prepared methyl ammonium and other alkyl-ammonium nitrites in pure crystalline state from silver nitrite and alkylamine hydrochloride. He isolated a very interesting series of compounds of the type $Br\text{-}C_2H_4(S\text{-}C_2H_4)_n\text{-}Br$. He prepared a number of double sulphates, having the form $2M^{II}SO_4\ (R_3S)_2SO_4 \cdot 10H_2O$ (where M^{II}=Fe, Zr, Ni, Co and Cd and R=CH_3 or C_2H_5) and studied their properties. He made a series of publications on the varying valency of platinum, gold and iridium. The reaction between platinic chloride, gold chloride or iridium tetrachloride and some organic sulphides gave rise to products in which the valency of Pt, Au or Ir seemed to vary.[15]

It is mentionworthy here that Ray's recognition as the father of chemical researches in India was not only due to his personal research, but also due to the inspiration he had given to the young researchers and his untiring efforts of developing an Indian School of Chemistry. Though he was not directly involved with the militant struggle for independence, he tried to establish the self-reliance of the Indians in both economic and scientific aspects. For fruition of his view, he attempted to impart proper education to his students in Presidency College even exclusive of university syllabus. His motto was to teach chemistry for developing a group of young chemists, who would be liable to enrich their motherland with original researches. He also revealed to his students the glorious past of the Indian Chemistry. He realised that the tuning between the scientific and technical education with the needs of the Indian Society was necessary, but it would never be done by the then existing education system controlled by the British. So he was strongly associated with the National Council of Education and in 1916, he joined the newly founded University College of Science as Palit Professor in Chemistry, leaving the Presidency College, a year earlier than his retirement. Ray had a strong desire of developing chemical industries in India by applying his chemical knowledge for the industrial and ultimately economic welfare of the country.

For fulfilment of his vision, he started to prepare common pharmaceutical products from the locally available ingredients and thus originated the Bengal Chemical and Pharmaceutical Works, with his meagre income and co-operation of his friends. This effort steadily flourished under his guidance.

Ray had a fascination for the history of science, particularly in the history of chemistry. He read Berthelot's Les Alchimistes Grecs (The Greek alchemist) and became stimulated with the idea of writing History of Hindu Chemistry on the model of Berthelot's work. Consequently, he published "History of Hindu Chemistry"[18] in two volumes (1902 and 1909) from the Asiatic Society.

He retired from the University College of Science in 1936 at the age of seventy-five. He was a life-long bachelor and led a very simple life. Actually, he established an ideal for the young generation through his own life. He donated his salary from 1921 to his date of retirement (which amounted to Rs. 1,80,000/-) to the Unversity fund for the extension and development of Chemistry Department as well as the creation of two Research Fellowships. Moreover, an annual research prize in chemistry of Rs. 10,000/- in 1922, named after the great Indian alchemist Nagarjuna and another research prize in Zoology in 1936 of Rs. 10,000/- named after Sir Asutosh Mookerji was donated by him. His autobiography "Life and Experiences of a Bengali Chemist"[19] was published in two volumes.

Ray's student, N. R. Dhar is the pioneer in researches in physical chemistry.[20] He started researches in 1915 at the Presidency College. An experiment by N. R. Dhar on the reduction of mercuric chloride in solution by oxalic acid in presence of oxidizing agent like potassium permanganate acting as catalyst was the first remarkable work in physical chemistry in India. Other illustrious names in this field are J. C. Ghosh, J. N. Mukherjee and S. S. Bhatnagar. S. S. Bhatnagar worked on the physico-chemical problems of emulsion at the University of Lahore.[21] J. C. Ghosh initiated the research in electro-

chemistry in India[22] and developed the theory of strong electrolytes during the period 1918-21. Magneto-chemistry studies in India started with the work of S. S. Bhatnagar at Lahore and D. M. Bose[23, 24] and P. Ray[25] at Calcutta. Bose first found that the values of moments of the ions of transition elements of the iron group are obtained only after considering the spin angular momentum of the unpaired electrons. The theoretical explanation of the above is given by Stoner[26] in 1929 and by van Vleck[27] in 1935. The 'spin only' formula is known as Bose-Stoner's formula.

Bhatnagar and his co-workers studied the relation between the magnetic and other properties (both physical and chemical) of substances. He devised a magnetic interference balance in collaboration with K. N. Mathur.[21] When the Second World War started, the British Govt. founded the Board of Scientific and Industrial Research, later renamed as the Council of Science and Industrial Research and Bhatnagar was appointed as its Director. Bhatnagar persuaded the Government to agree with the proposal of establishment of national laboratories in India, mooted originally by the Industrial Research Committee. After Independence he got a great opportunity for implementation of these proposals as he was a good friend of Jawaharlal Nehru, India's first Prime Minister. In 1943, he was elected the Honorary Fellow and later a Vice-President of the Society of Chemical Industry, London. In the same year, he was elected a Fellow of the Royal Society, London.

Debendra Mohan Bose (1885-1975)

After J. C. Bose's death, Debendra Mohan Bose, the distinguished physicist with international repute, became the Director of the Bose Institute. He was nephew of J. C. Bose and eight years' senior to both M. N. Saha and S. N. Bose. After passing M.A. in physics standing first in the first class form the Calcutta University he went abroad for advanced studies. He worked for sometime under the guidance of J. J. Thomson in the Cavendish Laboratory of England, where he had witnessed the epoch making work of C. T. Wilson in

developing his cloud chamber. In 1912, he obtained A. R.C.S. diploma as well as the B.Sc. degree with First Class from the University of London. Returning to Calcutta, he joined the City College as a Professor of Physics. In 1914, he joined the newly founded University College of Science as 'Ghosh Professor' in Physics, but within a few months left for Berlin with the Ghosh Travelling Fellowship of the University of Calcutta. When First World War broke out D. M. Bose became interned in Germany where he continued his work on the construction of a new type of Wilson Chamber in Prof. Regener's laboratory. Bose recorded the tracks of ionizing alpha and beta particles from radioactive source with the cloud chamber and photographed the tracks of recoil protons produced during the passage of fast moving alpha particles in a hydrogen filled chamber. From the result of the experiment with alpha particles Darwin's formula for collision between fast charged particles was verified. The results of these experiments were published in Physikalische Zeitschrift in 1916[28] and in Zeitschrift für Physik in 1923[29]. The researches on the history of Wilson Chamber around 1973 revealed an exciting fact, namely that, the artificial disintegration recorded photographically by Bose during 1914-18 anticipated that of Blackett. It is known from a letter written by Mr. Thaddeus J. Trenn of the University of Rogenburg to Dr. D. M. Bose in 1973.[23, 24] He returned to Calcutta in July, 1919 and then devoted himself to teach Physics in the University College of Science. In 1920 he constructed a cloud chamber and along with S. K. Ghosh, took photographs of recoil tracks of radioative nuclei during the process of alpha particle emission, A photograph obtained by him was interpreted as showing the disintegration of nitrogen nucleus, which received a hearty appreciation from Rutherford, when published in Nature (1923).

C. F. Powell, the famous physicist who won the Nobel Prize in 1947 for his discovery of mesons, acknowledged that he employed the same method of determining the mass of meson as devised by D. M. Bose and his colleague Biva Chaudhury, but the latter had to discontinue their experiment due to unavailability of good emulsions in the country.

In 1938 Bose joined the Bose Institute as Director and after that he was apparently busy with J. C. Bose's plant physiological studies till his death.

He was a founder fellow of Indian National Science Academy (INSA) and the First Editor of the Indian Journal of History of Science published by INSA.

Now we will discuss about two illustrious physicists, M. N. Saha[30] and S. N. Bose[31], who were all along good friends in spite of a strong competition existing throughout their career. Both of them studied their B.Sc. in the Presidency College with Honours in Mathematics and after that M.Sc. in mixed mathematics in the same year. In both the examinations, Bose stood first and Saha stood second. Sir Asutosh picked up both of them in 1916 as Lecturers in Mathematics in the University College of Science. But anyhow they could not adjust with Prof. Ganesh Prasad, the then Head of the Department of Applied Mathematics. Then Asutosh transferred them to the Physics Department though they had studied physics only upto B.Sc. pass level. So they began to study by themselves different branches of physics. At that time, D. M. Bose, the Ghosh Professor of Physics was interned in Germany. In July 1917, Asutosh appointed C. V. Raman as Palit Professor in physics in the University College of Science, but he continued his researches in the laboratory of the Indian Association for the Cultivation of Science. Saha and Bose knew German very well and within three years after the discovery of the General Theory of Relativity, they translated and published Einstein's papers. Together with a preface by P. C. Mahalanobis these were published by the University of Calcutta and meant for circulation in India only, an arrangement suggested by Einstein himself. The translated papers are also preserved in Einstein Archives at Princeton. It may be mentioned here that around 1920-28, three revolutionary discoveries were made by the Indians : thermal ionization theory (1920), Bose Statistics (1925) and Raman Effect (1928).

Contributions of Meghnad Saha

Saha's research on thermal ionization which brought him worldwide repute will be discussed first. During the second decade of the twentieth century, concept of physics was undergoing a radical change due to emergence of Bohr's quantum theory of hydrogen spectrum. Saha then applied himself to intensive studies of modern physics including quantum theory, Lorentz's electron theory, Einstein's theory of relativity. He applied his knowledge of the quantum theory to the problem of stellar spectra. At that time there were huge amounts of data on stellar spectra consisting of all kinds of irregularities and inconsistencies. Many spectral lines were missing while others, not expected, were there. These data gave birth to many speculations in different times by different authors, but the problem was still unsolved. It was Saha who removed many anomalies of those data and showed their application to the astronomical problems. Saha's equation of thermal ionization first appeared in the paper entitled "On ionization in the solar chromosphere" published in the Philosophical Magazine in October, 1920.[32] In this paper, he showed that the enhancement of chromospheric spectrum was due to lowering of pressure in the chromosphere.

He presumed that the very high temperature of the sun and other stellar bodies are responsible for all the changes in the constituent elements in them. A solid material was first converted into liquid and then into gas under the action of heat. If the gas is further heated it becomes ionized which is called thermal ionization. Saha deduced the exact value of ionization energies from the spectral data by applying his knowledge of thermodynamics :

$$\log \frac{X^2}{1-X^2} P = -\frac{U}{2.3\,RT} + \frac{5}{2} \log T - 6.5$$

where P is the total pressure, X is the fraction of ionized atoms,

U is the heat liberated in the ionization process, T is the temperature in Kelvin unit. The value 6.5 in the above expression is the value of the chemical constant obtained from the Sackur-Tetrode-Stern relation.[33-35] This equation shows that the degree of ionization greatly depends on pressure and temperature of the light source.[36] It can be used to determine the temperature of the star or the relative abundance of the chemical elements investigated. In 1927 Saha was elected to the Fellowship of the Royal Society, London for his fundamental contribution to thermal ionization. In response to Saha's work, the great astrophysicist Prof. Roseland commented : "It was the Indian physicist Meghnad Saha who (1920) first attempted to develop a consistent theory of the spectral sequence of the stars from the point of view of atomic theory ..... the impetus given to astrophysics by Saha's work can scarcely be overestimated, as merely all later progress in this field has been influenced by it and much of the subsequent work was the character of refinement of Saha's ideas."[37] It is a great pity that Saha had not got the Nobel Prize though his work on thermal ionization is regarded as one of the ten topmost works in astrophysics after the discovery of telescope by Gallileo.

Next, Saha prepared another three famous papers on this line, namely, "On elements of the sun"[38], "On the problems of temperature-radiation of gases"[39], "On the Harvard classification of stars"[40] and communicated them from India to the Philosophical Magazine during September, 1919. Sir Arthur Eddington expressed Saha's theory of Thermal Ionization as the twelfth important work in the history of astronomy.[41] He is known as the father of Astrophysics for his fundamental contribution to Astrophysics. After communicating his fourth paper, he went to London for experimental verification of his theory and according to the advice of his classmate, Snehamoy Dutta, then working in the Imperial College, met Prof. A. Fowler of the same college who worked earlier with the pioneer astrophysicist Sir Norman Lockyer. Fowler permitted him to work in his laboratory and enriched Saha with more stellar data and his knowledge about the stellar spectra. This induced Saha

to withdraw his fourth paper from the Philosophical Magazine and to revise and update it with the data supplied by Fowler. He communicated the revised version of the paper under the title "On a physical theory of stellar spectra"[40] to the Proceedings of the Royal Society, London. By this time, he also met J. J. Thomson but the Cavendish Laboratory had no provision for work at such high temperature.

After spending five months in Fowler's laboratory, he went to W. Nerst's laboratory in Berlin and worked there for one year, but the results were inconclusive. Saha had to hurry back to Calcutta getting an urgent call from Sir Asutosh asking him to return immediately and join the University College of Science as the first Khaira Professor of Physics on a salary of Rs.500/- per month, and a house allowance. In 1923, Saha left Science College as Professor and Head of the Department of Physics in the University of Allahabad, owing to lack of laboratory space, research grant and also partly due to some serious misunderstanding with C. V. Raman, the then Palit Professor of Physics.

At Allahabad, he passed most of his time preparing lecture notes. He also continued his work on thermal ionization and Astrophysics. Moreover, he initiated some new subjects such as statistical mechanics, atomic and molecular spectroscopy, propagation of radio waves in the ionosphere, physics of the upper atmosphere etc. He established a school of physics at Allahabad with a group of brilliant students, namely, R. K. Sur, G. R. Toshniwal, R. C. Majumdar, B. N. Srivastava, B. D. Nag Chowdhury, P. K. Kichlu, D. S. Kothari, G. S. Dube etc. During this time, he published jointly with Srivastava a text book on Heat, namely, 'A Treatise on Heat'. It is noteworthy, Saha described a method of calculating the pole strength of magnetic monopoles from fundamental principles in a paper entitled "The origin of the mass in neutrons and protons" published in the Indian Journal of Physics, Vol. 10, p. 141 (1935). P.A.M. Dirac also recognised in 1931 the existence of magnetic monopoles according to the demands of Quantum Mechanics, but the

magnetic monopoles have not yet been isolated. However, the relevant formula is known as Dirac-Saha formula. In 1932, he was elected the first President of U. P. Academy of Science, which was later renamed as the National Academy of Science, India (1934). In 1935, the Science News Association was founded by Saha with Sir P. C. Ray as President and himself as Secretary. Thus, he pioneered the creation of scientific organization in the country.

In 1938, Saha left Allahabad because it was impossible for him to work in the politically controlled atmosphere that had grown there. So he again joined the University College of Science, Calcutta as Palit Professor in the vacant post of D. M. Bose who by then joined as the Director of the Bose Institute. In Calcutta, Saha devoted his time to work in nuclear physics.

He had already seen cyclotron in Lawrence's Laboratory at Berkeley and decided to install a cyclotron at Calcutta. His student, B. D. Nag Chowdhury, was sent to work under Lawrence in 1938. It is mentionworthy that after coming to Calcutta, Saha entered the scene of national politics. He convinced Subhas Chandra Bose, the then Congress President, to constitute a National Planning Committee in Science and Culture in 1938. The discovery of nuclear fission by Otto Hahn and Lise Meitner in 1939 encouraged Saha to include nuclear physics as a special paper in M.Sc. syllabus. He raised Rs. 40,000/- form his pupils and others for building up a special laboratory for nuclear physics for this purpose. In the meantime, Saha managed munificent grants from both Birla and Tata groups, and also from Calcutta University for setting up the cyclotron at Calcutta, the critical parts and a 50 ton magnet for which were brought by B. D. Nag Chowdhury from Berkeley in 1942. He started a separate institute in the ground of University College of Science in 1951, which was later named after him. The first post M.Sc. course in nuclear physics was introduced in this institute. Saha achieved the sanction of a grant of Rs. 50 lakhs from the Atomic Energy Commission for the second five-year plan period (1955-60) for his institute, utilizing

political influence.[42] The area of research of the institute covered beta-ray spectroscopy, nuclear resonance and the use of the radioactive isotopes in medicine etc. Saha was elected Honorary Director for the Institute for life.

Saha had a keen interest regarding another Institute, the Indian Association for the Cultivation of Science. It is only due to Saha's effort and initiative, this institution got a permanent address in Jadavpur in 1951. He was the first Director of this institute and adorned this post till his death in 1953. Saha also took interest in the activity of the Asiatic Society. He was the President of the Asiatic Society and it is only due to his initiative that the outstanding book, 'The Upper Atmosphere' by S. K. Mitra was published by the Asiatic Society during this time.

In 1951, Saha was elected, as an independent candidate, to the Indian Parliament. His contribution to the debates in the House was particularly valuable in relation to subjects such as education, scientific research and many other aspects of everyday life.

Saha was much ahead of his time. He pointed out many problems and also gave their solutions some of which are :

1) Organization of scientific and industrial research
2) River Valley Project
3) Industrial use of the atomic energy
4) Planning the national economy
5) Modification of the Indian Calendar

In Calcutta, Saha Institute of Nuclear Physics, The Indian Association for the Cultivation of Science and the Journal, 'Science and Culture' will ever remain as evidence of his creative activity.

Important Works of Satyendranath Bose

The background of the second outstanding discovery of the third decade of twentieth century will be discussed now which was accomplished by the great scientist, Satyendranath

Bose.[31,43,44] The first important contribution of Bose in Theoretical Physics is a paper entitled "On the influence of the finite volume of molecules on the equation of state", jointly written with M. N. Saha and published in the Philosophical Magazine in 1918.[45] He left University College of Science in 1921, i.e. two years earlier than Saha and joined the Dacca University as Reader in Physics. Besides teaching and taking practical classes, Bose devoted much time to study original papers of Max Planck, Einstein, Bohr, Sommerfeld and especially Max Planck's book entitled "Thermodynamik and Warmestrahling" which was presented to him by D. M. Bose. It was the time when he wrote his famous paper entitled "Plancks Gesetz and Lichtquantenhypothese". This paper was translated by Einstein and published in Zeitschrift für Physik.[46] Einstein remarked on this paper : "Bose's method of derivation of Planck's law, in my opinion, signifies a forward step. The method used here gives also the quantum theory of an ideal gas as I shall show elsewhere."[31] Actually Bose's discovery laid the foundation of quantum statistics but it is astonishing that he had not got the Nobel Prize though all the scientists associated with the revolutionary works in quantum theory, relativity, the wave-particle concepts, quantum mechanics had received Nobel Prizes during the first third of this century. Planck introduced a new idea in Black body Radiation that energy is exchanged in the form of quanta the description of which required a new physics based on the quantum theory rather than the classical Maxwell -Boltzmann law. Bose immersed himself deeply on the work of Planck. He considered the black body radiation as a free photon gas and tried to derive Planck's law using light quantum hypothesis combined with statistical mechanics. Bose's postulate was that the photons are identical and indistinguishable particles and any number of them can occupy a given quantum state. Einstein extended Bose's work to massive particles and thus arose Bose Einstein statistics. The particles obeying this statistics are known as Bosons (the term was first used by P.A.M. Dirac in quantum electrodynamics).[31]

After Bose's discovery, a series of achievements came in the world of science : Fermi-Dirac Statistics for spin-half particles like electrons (1926), electro-magnetic field quantization by Heisenberg and Pauli (1929, 1930) and quantum electrodynamics by Dirac (1927, 1935).

In 1945, i.e., seven years later than M. N. Saha, Bose returned to Calcutta University as Khaira Professor of Physics. His second outstanding contribution in Mathematical Physics took place during this period. From 1916, Einstein was very busy with the formulation of his United Field Theory, but could not find out any exact solution of the field equations. Bose became interested in it after attending a seminar on this theory and tried his best to solve the problem. Ultimately, he succeeded in solving the equations of connection and published them in five important papers between 1953-1955. In the first two papers, he gave the solutions of the field equations and in the other three, he discussed the complete development of the physical theory and the relevant mathematical results were given. The importance of his work can be well understood from Schrodinger's remarks : "In the general case, it is next to impossible to produce it in a serveable tensorial form. It is hard to believe, unless one tries."[31]

He wrote many articles in Bengali on scientific matters, and believed that science can reach the common people only through the mother language. He founded Bangiya Bijnan Parishad and started a Bengali Journal named "Jnan-O-Bignan".

The Scientific contributions of C. V. Raman

The discovery of Raman Effect by C. V. Raman[47,48] ultimately brought the Nobel Prize in Physics (1930) to India. Research activities of Raman and his students include the following : Vibration and Sound, Theory of musical instruments, Wave Optics, Colloid studies; molecular scattering of light, X-rays, electron diffraction and crystal physics, Magnetism and Magneto-optics, Electro-optics and Dielectric Behavior, Raman Effect, viscosity of liquids, surface forces, line and band spectra and Optical and Electric properties of solids. Raman started his

investigation on scattering of light in 1919 in the Indian Association for the Cultivation of Science (IACS). He published a large number of papers on this topic, a few important ones of which will be mentioned here.

In 1922, he put forward a new theory that the blue colour of the sea water is not due to reflection of blue sky or due to suspended matter but due to molecular scattering of light. His elaborated work on the theory of light scattering in dense fluids was published in 1922. In 1921, Raman and K. S. Rao confirmed by repeated investigations that when sunlight is incident on distilled water, the depolarization of light scattered transversely by water increases enormously when a violet filter is introduced in the path of the incident light. K. S. Krishnan joined IACS as research associate to work with Raman. Krishnan made systematic investigations on the depolarization of light by 60 liquids. These data ultimately led Raman to think over the existence of optical analogue of the Compton Effect. Raman began to investigate with Krishnan the existence of a modified wavelength in the scattered beam. This was found to be true at last and became known as Raman Effect. When a beam of monochromatic light (single wavelength), say, green light of mercury arc passes through a transparent medium, new lines other that the incident one were found with frequencies $\gamma = \gamma_0 \pm \gamma_k$ to be present in the scattered beam, where γ_0 is the frequency of the incident beam. This new observation was studied by Raman and Krishnan in many liquids, solids and gases, thus proving the universality of the phenomena.[50] The results of these experiments were published in the Indian Journal of Physics in 1928,[51] and was first designated as Raman Effect by Pringsheim.

This theory of Raman effect was given by Raman and Krishnan and was published just after the discovery of the effect. They interpreted the origin of the antistokes (lines with higher frequency) as due to induced emissions from initially excited states of the molecules. These lines are very feeble because the ratio of the number of molecules in the excited state to that in the ground state is proportional to $e^{-h\gamma/KT}$ (from thermodynamical

consideration) where γ is the frequency of the line. The quantum mechanical theories of Raman effect were proposed by Monneyback, Planczek and others. If the incident radiation consisting of a stream of photon having energy $h\gamma$ (wher h is Planck's constant) undergoes collision with the molecules of the scattering material so that energy is not exchanged (perfectly elastic) between them, the incident beam will be deflected unchanged. However, if energy is exchanged between the photon and the molecule, the latter would gain or lose an amount of energy only in accordance with the quantal laws, i.e., the energy change ΔE must be the difference between two of its allowed states. If the molecule gains energy ΔE, the photon will be scattered with energy $h\gamma - \Delta E$ and the equivalent radiation will have a frequency $\gamma - \Delta E/h$. On the other hand, if the molecule loses energy ΔE, the scattered frequency will be $\gamma + \Delta E/h$. Since the former (Stokes' line) is accompanied by an increase in molecular energy while the latter (antistokes' line) involves a decrease, Stokes' radiation is generally more intense than the antistokes'. Experiments are carried out till now to furnish data regarding the number of Raman lines, their frequency shifts, polarization characters and relative intensities which inform regarding the structure of the molecules and their chemical combination.[52]

Now a few words will be said to clarify the public rumour regarding the personal relation between two great personalities, Saha and Raman,. It has been mentioned earlier in this paper that Saha left Khaira Professorship of Calcutta University partly because it became impossible for him to come to terms with Raman, who was the Head and the Palit Professor of Physics. It is also true that Saha was accidentally involved in the dispute with Raman in connection with IACS, when Raman had attempted to control IACS according to his whims. Then Saha, in response to a request of Shyamaprasad Mookherji, came into the picture in order to restrict Raman from such dictatorship. There is a rumour that Raman had been driven out by Saha from Calcutta but it is completely untrue, as Raman himself committed to Sukumar Chandra Sircar, assistant to Palit

Professor, that he had joined as the Director of Indian Institute of Science, Bangalore due to high salary and position it offered. However, Saha had deep regard for Raman which was revealed in one of his articles in which he described Raman's work in details.[53]

Homi Jahangir Bhabha

Another prominent name in Indian science in the first half of the twentieth century was Homi Jahangir Bhabha.[54,55] He was born on 30th October, 1910 and brought up in a highly cultured family of Bombay. His paternal aunt was married to Sir Dorabji Tata. His family was strongly nationalist and from his boyhood he was closely acquainted with Mahatma Gandhi and Nehru family. Bhabha joined Caius College, Cambridge in 1927 and obtained B.A. Degree in Mechanical Science Tripos in 1930. Though his father and uncle Dorab Tata intended to make him an Engineer and to join Tata Iron and Steel Company, he liked to study Theoretical Physics. His father promised that if he secured a First Class in mechanical science he could study whatever he desired. Hence, after passing Tripos he went on to work in Theoretical Physics at Cavendish Laboratory where Cockcroft, Walton, Blackett and Chadwick were working then on the structure of nucleus. He spent thirteen creative years of his youth in the West and came in contact with some of the greatest physicists of that time like W. Pauli, Niels Bohr, Heisenberg, Max Born, Fermi, Kramers etc. His original contribution to physics was in the field of cosmic radiation, the theory of elementary particles and quantum theory. His Cascade theory of electron showers in collaboration with W. Heitler in 1937, brought him a permanent reputation in the field of Theoretical physics. They calculated from relativistic quantum mechanics the number of secondary positive and negative electrons produced by a fast primary electron of energy E_0. He worked on the meson and predicted that the rate of decay of μ-mesons slows down with increasing velocity according to the relativity theory. Bhabha also worked on the creation of electron pairs in the collision of particles moving with relative velocity

comparable to that of light and found that the effective cross-section for the pair creation by fast proton in Lead is more than a thousand times larger than the cross-section for pair production by slow protons calculated by Heitler and Nordheim. He was the first person who calculated the cross-section for the electron-proton scattering, known as Bhabha Scattering. He was elected to the Fellowship of the Royal Society, London in 1941 for his outstanding contributions in Physics. In 1940, Bhabha accepted a post created for him as a Reader in Theoretical Physics at Indian Institute of Science (IISc), Bangalore. J. C. Ghosh was then the Director of IISc, but C. V. Raman was still there in the Department of Physics. Bhabha became the Professor of Cosmic Ray Research in 1942 and remained there upto 1945. During this time, the papers published by him dealt with the classical theory of point particles moving in general field and were more mathematical than his earlier ones.[54,56]

During his stay at Bangalore, he strongly felt the utility of the foundation of a big school of fundamental research in physics, both theoretical and experimental, which was essential for scientific developments, followed by industrial and economic developments of the country.[57] Hence, he proposed for an institute of fundamental research in India to Sir Dorab Tata, which was approved by Tata Trusts. After the war was over, Bhabha went to Bombay in December, 1945 to set up the Institute named as Tata Institute of Fundamental Research in a small bunglow on Peddar Road which was shifted to the old buildings of the Royal Bombay Yacht Club in 1948. The present building of Tata Institute was inaugurated in 1954 and the laboratory opened in 1962 by Jawaharlal Nehru. During this time, Bhabha was very busy with his administrative works related to the foundation of his new Institute, therefore, his purely scientific papers were not found after 1954. Even then he was closely associated with the researches carried out in his Institute. Prof. Bernard Peter was brought from USA to form a group of Cosmic Ray Research; Prof. K. Chandrasekhar formed a strong group in pure mathematics and Prof. D. Lal formed a geophysics group which worked on Cosmo-Geo-Astro physics.

M.G.K. Menon, being trained with Powell in Bristol joined the group of Prof. Peter who succeeded Bhabha as the Director of the Tata Institute. Bhabha recruited young researchers from all over India and continued to spare time with his young colleagues, even though he was becoming increasingly busy.

In 1948, Atomic Energy Commission was formed with Bhabha as Chairman, Bhatnagar as Secretary and Krishnan as a third member. The Commission decided to build an atomic energy establishment at Trombay. In 1954, Atomic Energy Commission was promoted to Department of Atomic Energy (DAE) which was charged particularly with the development of atomic energy for peaceful purposes and Bhabha was appointed as Secretary to the Govt. of India in the Department.[57]

The budget and facilities of atomic research steadily increased and its main centre was the Atomic Energy Centre at Trombay. On 12th January 1967, i.e., one year after Bhabha's accidental death, Mrs. Indira Gandhi, then Prime Minister of India, renamed the Centre as BhabhaAtomic Research Centre in India. The works of the Centre include research in the following subjects : physics, electronics, engineering, metallurgy and biology. The first reactor of IMW built by the scientists and engineers of the Centre was named APSARA for which fuel elements were supplied by United Kingdom Atomic Energy Authority. Bhabha required an extensive effort on the procurement and processing of ores, uranium metal fabrication, fuel element development and manufacture of irradiated fuel element, to be completely self-sufficient in a national nuclear power programme. To satisfy his vision, many fuel plants were developed among which the most sophisticated was the Plutonium Plant at the Trombay Centre which separates the Plutonium from fission products and other materials in irradiated fuel. Besides the plants at Trombay Centre, many other atomic energy plants were constructed while Bhabha was Secretary of Atomic Energy Commission. He was appointed President of the first United Nations Conference on the peaceful Uses of Atomic Energy held in Geneva in 1955. It was on this occasion

Bhabha proved himself as one of the leading figures in nuclear power generation in India.[57]

The present paper would be incomplete if we do not mention the names of Prasanta Chandra Mahalanobis (pioneer of research in Statistics in India), Ganesh Prasad (eminent mathematician), Sisir Kumar Mitra (father of the researches in Radiophysics and physics of the upper atmosphere). Mention must be made of Ramanujan who during his short life (1887-1920) had done a stupendous amount of work on the theory of numbers. Hopefully we can discuss the contributions of these men in a future article. These great men along with many others, built a strong base of modern science in India, driven by their strong patriotic feelings, spirit of self-reliance and untiring efforts for the revival of the golden heritage of their motherland.

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SECTION IV

SOME SALIENT FEATURES IN MODERN SCIENCE

IV - 1

SALIENT FEATURES OF MODERN PHYSICS AND THEIR RELEVANCE TO SOCIETY

C. K. MAJUMDAR

I. Introduction : Important Features in Physics of the 20th Century

Four important discoveries in physics made towards the end of the nineteenth century determined the character of physics in the twentieth century : H. Hertz[1] produced electromagnetic waves (1888); H. Becquerel[2] hit upon radioactivity (1896); K. Roentgen[3] found x-rays (1896), and J. J. Thomson discovered[4] the particle electron (1897) as a common constituent of all matter.

Theoretical work in thermodynamics in the nineteenth century led to the question[5] : what is the energy distribution in the spectrum of a perfectly black body? Theorists had no answer. Experimentalists took up the challenge and determined the distribution experimentally. In 1900, trying to explain this energy distribution M. Planck[6] introduced the idea of the quantum; energy was emitted and absorbed not in a continuous train but in packets. P. Lenard[7] found that photoelectrons (electrons driven out of a metal by ultraviolet radiation) were ejected instantaneously with exposure to radiation and their energy was determined by the frequency of the radiation, not by its intensity. A. Einstein[8] explained both features of the photoelectric effect by the quantum idea (1905). All the so-called permanent gases, oxygen, nitrogen

and hydrogen, were liquified; the rare gases were discovered and helium too was liquified at 4 K by Onnes[9] at Leyden (1908). Experiments at low temperature showed that the specific heat of solids diminished at low temperature; Einstein and P. Debye[10] explained this successfully through the quantum idea.

By 1912, E. Rutherford[11] was able to establish that the positive charge in an atom was concentrated in a small volume called the nucleus. In 1913, N. Bohr[12] explained the spectrum of atomic hydrogen by postulating that there are stationary states in the atom and that radiaion is emitted or absorbed when the atom makes a transition between the stationary states.

Experimental work confirmed duality[13], that is a particle has a wave associatied with it just as light occasionally behaves like particles. Light particles are called 'photons'. A mathematically consistent mechanics for the atom, known as quantum mechanics[14], was formulated by W. Heisenberg and E. Schroedinger(1925-26)[15]. The deterministic nature of classical mechanics was replaced by probablistic notions; in quantum mechanics one can calculate the probabilities of the results of an expeiment. Also some quantities cannot be simultaneously measured with infinite precision. The product of uncertainties in the simultaneous measurements of position and momentum of a particle can be shown to have a definite lower bound; this is the uncertainty principle (1927).[16]

Meanwhile in the special theory of relativity (1905) Einstein[17] radically revised the idea of space and time. His analysis of the notion of simultaneity showed that two events simultaneous with respect to one observer need not be so to another moving uniformly in a straight line with respect to the former. Later (1916) in the general theory of relativity, Einstein[18] showed that gravitation could be incorporated as a property of curved geometry of space-time.

Some metals emit electrons on heating (thermionic emission)[19]. The science of electronics came into existence with vacuum tubes—evacuated glass tubes with several electrodes sealed in, to control the motion of electrons; they could generate, detect

and amplify radio signals. Wireless radio communication replaced older telephonic and telegraphic communication. In radio broadcast voice was transmitted; very soon, in television, pictures could also be transmitted. The world of entertainment changed altogether through the cinema. The vacuum tubes consumed much electricity and were difficult to handle. After World War II, the Bell Telephone Laboratories in the United States marketed a new solid state device "transistor" based on germanium or silicon[20]. Transistors were small, required little power and were rugged, but they could take over the functions of vacuum tubes. Other solid state devices were progressively based on thin films, and the trend was to miniaturise; hundreds of transistors were produced on a single silicon piece, popularly called a 'chip'.

One of the big benefits of these developments was the computer.[21] During World War II, electronic computing devices were introduced. During the next few decades the computer went through several generations. At first the big vacuum tube machines had instructions stored in the 'memory' of the machines, but they were specific to them. Then higher level languages for these instructions were developed to make them independent of specific machines. Transistors, magnetic tapes and silicon chips greatly reduced the size of the machines, but increased their reliability and computing power. In the eighties small personal computers were introduced, but they could be linked together in a network spread over a wide area. There are several worldwide networks today, and artificial satellites and computers have made international direct dialling in telephone calls possible.

The availability of small, light-weight, rugged and reliable solid state devices and computers also helped in the programmes of artificial satellites. After World War II the rocket propulsion was vastly improved and their control perfected, so that artificial satellites could be launched, and a landing of the Moon by man was possible. Space travel after breaking out from the confines of the Earth has become a distinct possibility.

Amplification of visible light was made possible through lasers.

Light from laser has the propertyof directional propagation and can be piped through optical fibres; they provide many advàntages in signal propagation and will be increasingly used in communication in future.

The discovery of the nucleus led to the recognition of very strong nuclear forces and opened the vista for nuclear energy[22]. E. Fermi was able to design and operate a nuclear reactor (1942) in which energy was extracted in the fission mode, that is by breaking a big nucleus. The fusion mode of extraction energy by fusing or melting some light nuclei together operates in the Sun and other stars, but a fusion reactor has not been realised yet. Unfortunately weapons with enormous power of destruction, using both fission and fusion modes, were produced. Two crude fission bombs were actually used near the end of World War II to destroy two Japanese cities Hiroshima and Nagasaki (Aug 6 and 9, 1945).

It was recognised that radioactivity involved anoher new force—the weak force, weaker than the nuclear and the electrical forces. Heavy atoms like uranium or radium disintegrate spontaneously with a characteristc lifetime. Even some lighter atoms show radioactivity; for example, hydrogen with one proton in the nucleus is stable, but tritium with one porton and two neutrons in the nucleus is radioactive, though chemically tritium are isotopes; they have the same number of protons in the nucleus and are therefore placed in the same position in the Peridic Table of atoms, but radioactivity of tritium enables one to track its behaviour in various chemical processes. For unravelling the structure and properties of large molecules, such 'tagging' (replacing one chemical element by its radioactive isotope) has helped enormously. One science that gained tremendously is genetics. The new science of molecular biology was born around 1950 through the efforts of physicists.

The vision of unlimited energy through nuclear processes has been obscured by the fear of annihilation of mankind through accidents in nuclear reactors or misuse of nuclear weapons. Hence the trend is to move away fom nuclear energy. Physicists

are trying to utilise the solar energy more efficiently. Solar cells and concentrators are being designed and used, particularly in the tropical countries, to meet their increasing energy demands.

II. Spread of modern physics in India

India was a colony in the British empire, but was the first Asian country before Japan and China to have scientists participate in the developments in physics in the first quarter of the 20th century. Foundations for this participation were laid in the last century. Mahendralal Sircar had founded the Indian Association for the Cultivation of Science in 1876.[23] It was the first organised research institute in Calcutta. Lectures in physics were given by Sircar himself, E. Lafont, Jagadis Chandra Bose, and Asutosh Mookerjee. Sircar died in 1904; apparently, at the time of his death , he felt frustrated that adequate progress was not made. Three years later (1907) a high-ranking government officer Chandrasekhar Venkataraman, highly educated and full of curiosity in science, knocked at the door of the Association. A worker Asutosh De, with moderate education but with a modicum of practical skill, opened the door, and took him to the Secretary Sri Amritalal Sircar. It was the turning point. The man of ideas met the man with skill, and their work changed the course of the Association for ever. Other workers came; Raman gave up his government job, became a university professor and a full time research scientist. The address 210 Bowbazar Street became known all over the world through the work of Indian scientists in acoustics, optics, spectroscopy and magnetism.

Around 1900, Presidency College, Calcutta, had three distinguished Indian research scientsts on the staff. Jagadis Chandra Bose discovered the microwaves (1896); these are electromagnetic waves with wavelength of a few millmetres; later he went over to electrophysiology, botany and biophysics. Prafulla Chandra Ray did original research in inorganic chemistry. D. N. Mallik published research work in mathematics. (There was also A. Pedler, a distinguished English chemist.) They inspired a group of students who became well-known scientists later. The batch of undergraduate students in 1909-1913 contained S. N.

Bose, M. N. Saha, J. C. Ghosh and J. N. Mukherjee. S. K. Mitra and P. C. Mahalanobis were also there, some years senior to them.

The University College of Science and Technology in Calcutta was founded in 1914 by the efforts of Asutosh Mookerjee, who managed to obtain munificent donations from Taraknath Palit, Rashbehary Ghosh and Raja Guruprasad Singh and Rani Bageswari of Khaira. While establishing the Palit professorships of Physics and Chemistry, A Mookerjee insisted on the condition that the professors must be of Indian origin[25]. C. V. Raman and P. C. Ray were Palit Professor of Physics and Chemistry, respectively; D. M. Bose was Ghosh Professor of Physics. A. Mookerjee also insisted that junior teachers would be allowed to teach the Master's course only when they published some original research work. Two parallel developments should be mentioned; P. C. Ray pioneered in chemical industry in India and started the Bengal Chemical in Calcutta. Meanwhile at Sakchi (Jamshedpur) at the confluence of the river Subarnarekha and Kharki, the first indigenous steel industry was established (1908). Pramathanath Bose, an Indian geologst, played a prominent part in the choice of the site.

The lead of the Calcutta University was soon followed by other universities. The newly established (1912) university at Dacca (now spelt Dhaka in Bangladesh) had a good group in physics in spectroscopy, x-rays and magnetism. The physics department of Allahabad was established (1923) with M. N. Saha as its head; later, when he left, K. S. Krishnan replaced him (1942). Very soon research groups were organised in Benares Hindu Unversity at Varanasi, Andhra University at Waltair, the Delhi University in New Delhi, and elsewhere. Raman moved to Indian Institute of Science at Bangalore in 1933 and started new activities there.

The need for regular communication among research workers was also felt early. A. Mookerjee established the Indian Science Congress Association (ISCA) which began its annual meeting in 1914. Over the years this meeting has grown very large. The

increase in the numbers of specializations gave rise to special annual meetings, for instance in particle physics, nuclear physics and condensed matter physics. The ISCA is still a forum for all scientists and serves as a meeting ground of scientists and the general interested public. New ideas are sorely needed to ensure the effectiveness of ISCA.

There are three science academies in India : the Indian Academy of Science in Bangalore (started in 1934), the Indian National Science Academy in New Delhi (started in 1935), and the National Academy of Sciences at Allababad (started in 1930). They also organize meetings to encourage physics research.

The spread of scientific education and research during the first half of this century, even when India was a colony, was in fact a part of the national aspiration. But the old adage that great Scientists are born and not made was dramatically demonstrated by the mathematician Srinivasa Ramanujan[26]. He was a native genius in the great Indian tradition of Aryabhata, Bhaskaracharya and Brahmagupta. The story how he wrote a letter to the English mathematician G. H. Hardy who recognized his genius and arranged his visit to England is well known. Ramanujan's exposure to the western world improved his presentation; his results were given decent and rigorous proofs, but his invincible originality and deep intuition marked him out as a great mathematician. Mathematical physicists have found his results useful in many problems.

III. Early contribution by Indians to modern physics

We shall describe in general terms the important Indian contributions to the develpment of quatum physics.

M. N. Saha[27] made a fundamental contribution to astrophysics in his theory of thermal ionization (1920). The atom has its positive electrical charge concentrated in a tiny core, the nucleus, and has equal amount of negative electrical charge carried by several electrons outside the nucleus. When energy is supplied to the atom some of these electrons can be detached; the atom becomes an "ion". The thermal energy in the stars like the Sun

can produce ionizaton, and thermodynamics applied to the process can determine the degree of ionization. Light from the stars, rather the spectra of the stars—because we record more than visible light—can tell us about their constitution and pressure and temperture.

S. N. Bose's work (1924) started quantum statistics[28]. In classical mechanics identical particles are regarded as distinguishable because each particle can in principle be followed through its trajectory. Bose showed that Planck's law for the distribution of energy in black-body radiation can be explained if identical particles are regarded as indistinguishable. A particle in quantum mechanics has a wave associated with it, and the notion of a precise trajectory is lost when two particles collide and their associated waves overlap and, as they separate out again, we cannot say which is which.

C. V. Raman's researches in light scattering[29] from liquids led to the discovery of the Raman Effect (1928). When light of definite frequency is scattered from a liquid, we get light of the original frequency but also light with frequencies shifted downward (Stokes lines) and upward (anti-Stokes lines). The frequency shifts are independent of the frequency of the incoming light and are characteristic of the liquid. Using visible light in the Raman Efect, it is possible to know the spectra of liquids in the infrared region. C. V. Raman was awarded the Nobel Prize in Physics in 1930.

Magnetism is found in salts of the transition elements or rare earths. This is due to orbital motion of the electrons and to the spin of the electron, a characteristic quantum property. D. M. Bose[30] showed that salts of the 3d series (elements like titanium, chromium, iron, cobalt and nickel) show magentism due to spin alone (1926). Later K. S. Krishnan[31] devised two experimental methods—the oscillation method and the critical couple method—to measure anisotropies in magnetic properties, and showed that magnetic methods complemented x-ray ones in the determination of crystal structures. In the latter field, K. Banerjee[32] initiated the problem of phase determination, which was successfully tackled

much later with powerful computers.

When quantum mechanics was being formulated, one Indian scientist B. B. Roy expressed strong reservations in a letter : "I fear, if atomic physics has to progress on the line of Born and Jordan, you will find very few people left in the atomic physics circle." Inadequate training in mathematics proved to be a barrier to many Indian physicists in their attempt to assimilate the quantum mechanical ideas.

It should be mentioned that the famous papers on relativity by Albert Einstein, including one on the general theory of relativity, were first translated from German into English by M. N. Saha and S. N. Bose.[34]

The success of young Indian scientists gave legitimacy to scientific research as a profession and their international recognition added some glamour and social prestige to it. Much has changed since independence, but in Calcutta and its neighbourhood, the mystique of scientific discoveries still has enough attraction for young students. There the educational standards deteriorated sharply in the last quarter of this century, but young and bright students seek opportunities elsewhere in India and abroad to pursue careers in science.

IV. Uncertainty Principle and Probability

The impact of quantum mechanics on the Western philosophy was profound. Quantum mechanics involves probabilistic ideas at a level deeper than familiar probabilistic ideas in games of chance. We have already mentioned the uncertainty principle. Determinism prevalent in classical mechanics was lost. Scientists like M. Planck deliberated a great deal on "free will".

I understand from Indian philosophers that the impact of this new development on Indian philosophical doctrines was less profound. The Indian doctrines allowed great variety, strongly theistic to epicureanism, agnosticism and atheism. As modern physics becomes more familiar to Indians, there may yet be stronger reaction from Indian philosophers.

V. Planning

In 1939, the Indian National Congress set up a committee for planning the development of India. Later it gave rise to the Council of Scientific and Industrial Research (1942). Now there are more than forty laboratories under the Council, including the National Physical Laboratory (NPL) in New Delhi and the National Chemical Laboratory at Pune. The NPL is the custodian of standards in mass, length, time, and thermophysical and electrical quantities. The extramural research (EMR) division of CSIR was the only source of research funds for universites and research institutes immediately after independence. Even today young scientists can obtain funds from it for initiating their research projects. Larger funds can now be obtained from the Department of Science and Technology (DST).

The Indian planning took a new direction with the establishment of the Indian Statistical Institute (ISI). P. C. Mahalanobis, professor of physics at Presidency College, Calcutta, (1916-46) was familiar with the statistical analysis of errors in physics experiments, became interested in wider applications of statistical methods and established a statistical laboratory in the Physics Department. This grew into the institute in Calcutta, and later established branches in several other cities, and has now become indispensable in the overall planning for the country.

We should also mention that the Indian parliament passed in 1958 a "Scientific Policy Resolution" aiming "to foster, promote and sustain, by all appropriate means the cultivation of science and scientific research in all its aspects, pure, applied and educational....".

VI. Nuclear Research

Even before the nuclear energy burst upon the popular consciousness with the horror of Hiroshima and Nagasaki, two Indian scientists, M. N. Saha in Calcutta and H. J. Bhabha in Bangalore, had been keenly following the evolution of nuclear research. They anticipated the importance of nuclear research in

India, specially the prospect of nuclear energy. With the help of the Tata Group of industries, Bhabha started the Tata Institute of Fundamental Research in Mumbai (1945). Saha set up a cyclotron laboratory in Calcutta University and established later an Institute of Nuclear Physics (inaugurated by Irene Joliot-Curie in 1951, and renamed Saha Institute of Nuclear Physics, after Saha's death in 1956). After independence, nuclear physics was a very fashionable subject and many universities started teaching nuclear physics. The fear of nuclear weapons slowly produced a strong negative reaction everywhere. All major countries tried to have strict control over nuclear research and development. India also established by an act of the Parliament (1948), the Atomic Energy Commisssion with H. J. Bhabha as Chairman (1955); the Department of Atomic Energy was established in 1954, and all nuclear research was brought under its control. The progress since that time can be examined under three heads : pure research, nuclear energy and nuclear weapons.

Apart from the old cyclotron in Calcutta, the Punjab University at Chandigarh got a cyclotron from the University of Rochester, USA. Calcutta now has a variable energy cyclotron. Several universities got Van de Graaf generators for accelerating particles. The Tata Institute of Fundamental Research in Mumbai and the Nuclear Science Centre in New Delhi have each got a pelletron machine; the Institute of Physics, Bhubaneswar, has got a horizontal pelletron of lower terminal voltage. Machines which accelerate ions to between 50 and 800 Kev are utilized for ion implantation useful in solid state devices; several ion implantation facilities are available in the country. Radiation detectors and particle counters were produced and marketed by the Electronic Corporation of India. Universites, however, found that nuclear research was prohibitively costly. The interest of the students declined as jobs using nuclear expertise were shrinking in number. Some universities started concentrating on radiation physics, which imparts training in the use of radioisotopes and in radiation therapy. Radioisotopes are increasingly used in agriculture and medicine; radiation has also been used for food preservation.

On the international scene, studies of nuclear physics led to the study of particles—constituents of nuclei. Big accelerators were necessary and were beyond India's financial capacity. Accelerators can go up to a finite though high energy. Cosmic rays that hit the Earth from the surrounding space do not have such a limitation. Indian workers did valuable work in cosmic ray research, sometimes sending balloons up in the atmosphere, sometimes going down in deep gold mines at Kolar with detectors. But the flux of cosmic rays is low and the scientific output is no more commensurate with the money and effort spent in the work. There was a competition between the United States and Soviet Union for building bigger and bigger accelarators; the two mile long Stanford linear accelerator centre (SLAC) in California, USA, and the accelerator at Dubna, USSR, are examples. Ultimately a stage was reached when international collaboration was the only possible solution. The Centre for European Nuclear Research (CERN) at Geneva, Switzerland, is an international effort; even Indian workers participate in experiments done there.

The nuclear energy programme[37] started with small research reactors at Trombay, e.g. Apsara and Zerlina. The nuclear power programme is based on CANDU type reactors which use natural uranium as fuel and heavy water as moderator. Power reactors operate at Rana Pratap Sagar (Rajasthan), Narora (UP), Kalpakkam (Tamilnadu), etc. Research on a breeder reactor which will produce fuel for another reactor is also going on. India has plenty of thorium, and someday thorium may replace uranium as fuel.

The use of nuclear energy has become restricted by the fear of accidents in reactors which may be catastrophic (as in Chernobyl in Soviet Union) and by the problem of nuclear waste disposal. The safety requirements in any nuclear reactor are far more stringent than those in any thermal power station; yet accidents do happen; even small leaks may become pretty troublesome. The nuclear waste remains radioactive and dangerous for hundreds of years. The present solution is to contain it in sealed containers, difficult to break, and bury them deep inside the earth

in remote areas; alternatively the waste may be thrown in subductive zones in the border of a tectonic plate where it will go deep inside the earth by natural processes.

Let me quickly dispose of the nuclear weapons problem. The bombs in World War II used the fuels uranium and plutonium in the fission process. Later the destructive power was shown to be more for a nuclear weapon operated by the fusion process; in the hydrogen bomb hydrogen nuclei are fused to form helium nuclei. In May 1974, the first atomic explosion at Pokhran by India was called a peaceful nuclear explosion(PNE) because the experiment had some scientific components—study of phase transformation under high temperature and high pressure, cracking rocks to stimulate oil flow inside the earth, etc. In May 1998 India exploded five nuclear devices, perhaps including one hydrogen device, which were basically weapons. Most Indians felt proud of the achievements by their scientists. Some are deeply disturbed and feel that it was ethically wrong to induct nuclear weapons in the Indian subcontinent[38]. Their opponents opine that defence preparedness cannot be compromised because of ethical principles. It has been argued that money for such weapons should have been better spent for economic growth; this has been countered by pointing out that the expenditure is a small fraction of the defence budget. In any case, the movement to the ideal situation in which all nations will agree to abjure nuclear weapons has not taken off.

VII. Energy

One measure of the quality of life in country is the amount of per capita energy consumption. This is low in India. The potential of nuclear energy is high; it is also concentrated and high grade, but the capital cost for the installation of a nuclear power plant is high, and the other perils have been noted above. What are the alternatives? India's known oil reserve is not high. The oil and Natural Gas Commission did not get much, except oil in Bombay High off the coast of Maharashtra and gas in the far eastern state of Manipur. Oil and gas, like coal, are not renewable resources. Coal reserves are getting depleted; thermal stations also cause a

lot of pollution. The other nuclear route of fusion can be achieved in either of two ways : magnetic confinement of fuel in the form of plasma and inertial confinement of fuel with laser ignition. The international estimate is that a plasma fusion reactor is not going to be practical in the next two or three decades. The laser route is still trying to find ways to deliver the laser energy to the pressurised deuterium-tritium pellet fast enough.

For the last two decades there has been much talk about "non-conventional" energy which includes solar energy and energy from biomass. The term "non-conventional" appears to be a misnomer in India because solar energy and energy from biomass are the only familiar energy to much of rural India and have been so from time immemorial. M. N. Saha estimated[39] that energy from biomass was meeting 64.4 percent of the energy requirement (1954). The alarming deforestation in India since independence is an indication that wood has continued to be the dominant fuel. Gobar gas plant was a nice innovation; but its operation requires a minimum number of cattle; villages in the far eastern states, where each family may own one or two cows but is not willing to contribute to the common fuel pool, are not able to utilise such plants : there is some social reluctance to adapt to the new technology.

Solar energy is diffuse and low-grade, but is ubiquitous. Its utilisation through silicon cells has made steady progress; the cell efficiency has increased, though all the problems of degradation are not solved or even understood. In some areas where abundant sunlight is available throughout the year and in special situations of remote areas, the solar cell has been used.

An interesting idea in biotechnology has been proposed.[40] Can we genetically breed plants which will convert sunlight through photosynthesis directly into fuel and deliver it through the roots? It is too early to judge the prospects of such an idea.

VIII. Radioscience : Space Science

The radio broadcasting[41] in India started with vacuum tube technology (1925). A radio receiver set at the time of

independence was quite costly and required the standard 220 volt electric supply. Outside cities and towns, the set could be operated with a bank of batteries which had to be periodically recharged. Still some rich men in villages got radiosets; their homesteads became centres of attraction during daily news and by controlling the source of information they were able to increase their prestige and power in the village. The introduction of the transistor changed the scene radically. The receiver sets could be operated on torch batteries, long familiar in India, and were small, ragged and portable. They were also much cheaper. Information was much nore freely available, and from the time of the second general election in 1957, the base of democracy in India was strengthened by this development.

Propagation of radio waves over long distances was helped by the ionosphere. At least three layers E, F and D were found. Researches in the upper atmosphere were started by S. K. Mitra and his students. Balloons (radiosondes) were sent up regularly. It was found that the earth's magnetic equator passed through the southern tip of the Deccan peninsula and Thumba was an excellent location for sending rockets up. Rockets could gather information only for a short time during the flight. The Physical Research Laboratory at Ahmedabad and the National Physical Laboratory in New Delhi were prominent in these programmes.

Television was introduced in India about a decade after independence; its range was limited, so several stations were set up near bigger cities. To cover remote areas, the satellite instruction technology experiment (SITE) was tried in 1975. Advanced countries had already sent up many orbitting satellites; programmes could be sent up to them from a main station, stored in them, and then beamed into receiving antennas set up in remote areas and distributed in these areas.

Such programmes require international collaboration. The Indian Space Research Organisation (ISRO) with its headquarters near Bangalore was set up (1972) to coordinate various activities, of which some may be mentioned.[42] Remote sensing involves taking pictures using some part of the electromagnetic

spectrum (visible and infrared) by sensitive cameras carried in helicopters or artificial satellites. This is very important in estimating agricultural crop in India. Agriculture in India is still critically dependent on monsoon. So the prediction of monsoon, in general weather forecast over a short or a long range, has been of interest (for example MONEX project). While long range forecast may not be possible because of the inherent complexity or chaotic nature of the problem, some significant developments should be mentioned. It is well known that cyclones occur frequently in the Bay of Bengal, some of them quite devastating, and the coastal areas had suffered enormous loss in life and property. Radar system especially the powerful MST (mesospheric, stratospheric and tropospheric) radar warning system was set up in the eighties along the Bay of Bengal coast and early warning of cyclones has cut down the loss of human life considerably. The warning is passed on to the neighbouring country Bangladesh as well.

Artificial satellites and geostationary satellites revolutionized telecommunication. Today one can make telephone calls directly from one continent to another as easily as from one part of a city to another. The availibility of electronic mail through computer network has made even letter writing old fashioned.

The development of sensitive radio antennas and radioreceivers opened a new window in the old science of astronomy, because it was found that the Sun, the planet Jupiter, and some stars emit radiowaves. Similarly, sensitive microwave antennas detected the universal 2.7 K background radiation which is supposed to be remnant of the big bang that occurred at the beginning of the universe. Sending appropriate detectors up in the artificial satellites, the sky has been mapped in various parts of the electromagnetic spectrum : infrared, ultraviolet, x-rays and gamma rays. The cosmic background explorer (COBE) experiment tried to detect anisotropies in the 2.7 K radiation. The radiotelescope set up at Ooty by the Tata Institute of Fundamental Research was the first major facility in India in this new field. Later the construction of the Giant Metrewave Radiotelescope near Pune

was undertaken; this is the largest facility in the world in the metrewave range.

IX. Computer

The first electronic computer came to the Indian Statistical Institute in Calcutta in the early fifties. Fear of new technology in the early stage of the Industrial Revolution was known to have led to peculiar public response; a new word "luddite" was introduced in the English language from these experiences. Instead of waiting and watching, politicians in the state of West Bengal discouarged the introduction of the computer and encouraged irrational arguments like loss of jobs. Any successful technology leads to creation of more jobs. The workforce has to be retrained and new educational channels have to be opened to generate technical manpower; these were not done. This was a major setback for the technological development in and around Calcutta, although the technical skill of its labour force was high and the Calcutta University had an advanced centre for radiophysics and electronics.

The computer proved to be a successful technology, and has now penetrated into many aspects of Indian life. The hardware capability is not as high as the software capability in India. Internationally technology changes very fast in this field. Neither Indian industry nor Indian science and technology has the wherewithal to keep up with the fast change. On the software side, the ability for abstract thinking and mathematical and analytical skills of Indians prove to be an asset.

X. Social reactions to Physics research requirements

After independence India followed a strategy of having a few well-funded research institutes. It allowed her to maintain visibility in world science and her success in nuclear, space and energy research mentioned above came from these centres. This policy contradicted the strongly held opinion that it was wrong to " separate teaching from research, assigning teaching to universities and research to research institutes and research establishments". This state of affairs simply could not continue

indefinitely, for universities supply manpower for research establishments also.

The cost of higher education, especially high quality scientific and technical training, is relatively high. The Indian Institutes of Technology maintain a high standard; the tuition fees have been raised recently and may be raised again in near future, going ulitmately beyond the capacity of the middle class people who supply the largest fraction of bright students. This is a dangerous trend, as the conditions of universities have not been improved at all.

The cost of higher education and research is met, to some extent, from private donation and from support by industries. We mentioned how, before independence, private donation started off science research at Calcutta University and the nuclear research in Calcutta and Mumbai. Such private support has been dwindling. Because politicians infiltrated into the management of universities and colleges and produced the sorry plight of mismanagement, the private donor cannot trust the university management anymore. It is well known that religious missions are still thriving and running educational institutions (schools and colleges), so private donation is still available and can be tapped if universities are managed better.

The cooperation between science and industry was achieved in German chemical industry in the early part of this century; this has been successfully done in all disciplines in the United States too. The industry in India is not enlightened enough and is often satisfied with old technology borrowed from abroad. The chaotic conditions to which Indian universities are reduced are impediments, because industry would like to support time-bound, product-oriented research, but the universities do not maintain proper time scales even in examinations. Only on rare occasions the defence laboratories or the naval and aeronautic laboratories have asked for help from research institutions, but this trend is likely to grow in future.

We have mentioned the change in style of research in accelerator and particle physics. Multi-institutional laboratories

are normal in Europe and America. The Nuclear Science Centre (NSC) in Delhi and the inter-university centres for Department of Atomic Energy facilities (IUC-DAEF) in Indore, Mumbai and Calcutta have just begun functioning ; we have to learn how to run them efficiently and manage them harmoniously. The difficulties in the Gobar gas plants were mentioned; a new social awareness or a new innovation would be necessary; the former is harder to awake, so the latter is a challenge to physicists and engineers.

Fast changes in electronics and computer technology forced people everywhere to think of " continuing education" or "distance education" or " teachers retraining schools". This trend is also likely to grow.

We should say a few words about the effect on literature, particularly because of the exciting possibilities of space travel. Science fiction has become a respectable part of literature and is growing. The Indian literature of this genre is not as richly endowed as the American and the European literature. However, as the scientific culture spreads in India, the literature will be enriched; after all, the epic poets of yore centainly did not lack imagination about aerial flight, camouflage or weapons of incredible power.

In the West a survey was conducted to find out what discoveries and inventions in physics affected the quality of daily life maximally. The winners turned out to be electric power, automobile and airplanes. This sounds like a subaltern view, but it is not, as the respondents were high academicians well aware of the great ideas of physics : relativity, quantum mechanics, molecular biology, DNA and all that. One wonders what will be the winners in India. I shall hazard a guess: electric power, railways, and transistor radio.

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IV - 2

BIOLOGY IN THE 20TH CENTURY

R.L. BRAHMACHARY

As I take stock of the achievements and trends developed in this branch of science at the end of this century (1999) two features strike me with overwhelming force.

On the one hand scientific problems are being tackled in the laboratory with the help of the most sophisticated technology getting increasingly complex and on the other, an ever-increasing number of investigators is going out for field work, observing plants and animals in all possible niches, from the African savannah or steaming tropical rainforest to the frozen Antarctica.

Equally impressive to me is the two-pronged attack, one aiming at the loftiest level of intellectual thought trying to probe the innermost secrets of life and mind and the other concerning itself with down to earth practical problems of our environment. The cynic may point out, rightly perhaps, that problems caused by ecopollution or excessive plundering of Nature are a consequence of this science itself. He may also observe, with grim pleasure, that never before was scientific research so expensive, draining the resources of Nations, getting out of reach of the poor countries and so threatened by the danger of breaking down by its own weight and sucking off all available funds.

1. Grappling with the abstruse

a) How the chick is made from an egg.

From time immemorial the greatest thinkers, philosophers and scientists, have been questioning the nature of life itself, its origin and development and such problems. One of the greatest of these thinkers, Aristotle, was a biologist *par excellence,* a "field-biologist" (as we would term to-day) as well as a great theoretician. He formulated in a relatively precise way one of the most challenging problems-how can an animal with all its complicated body machinery arise out of an egg, how such diversity arises out of a primordial simplicity? (In to-day's parlance this question embodies the twin science of embryology and genetics). More specifically, does the egg contain a preformed pattern of the future body? If so, then this blueprint contains within itself the blueprints of the bodies of all future generations telescoped into the first in an unimaginably microscopic manner (preformation theory). If not, then the birth of every hen from an egg would be a miracle- a complex pattern emerging out of nothingness (epigenesis). Aristotle tried to answer the question (which embodies the twin science of embryology and genetics) by breaking open and observing progressively maturing eggs. This trend of observation and experimentation took a back seat later on and mystics like Paley held sway even in Darwin's days. Paley argued this way: the existence of a watch proves that of the watchmaker. An animal, a fowl or a human being, is a far more intricate machinery than a watch (a view that only gained greater strength with increasing knowledge of Anatomy and Physiology) and so do they not indicate the existence of a creator?

In the late nineteenth century men like Roux and Driesch, Bataillon and Loeb initiated the science of experimental embryology and artificial parthenogenesis. In short, the new sciences showed that the problem raised by Aristotle could be probed at a deeper level in a more exact manner. The mystery of one of the two microcosms, the sperm (not known as such to Aristotle) seemed to vanish with artificial fertilization by means of physicochemical stimuli and the blueprint of the body, first

emerging in a manner not yet clearly understood, appeared to have been fixed at a certain developmental stage and mapped in different parts of the embryo in a rather accurate manner. This was the invaluable legacy of the nineteenth century acquired by ours and in the space of a hundred years or so a spectacular development took place. Again, interestingly, Mendel's study suggesting that heredity is due to an interplay of tangible factors obeying laws of Nature much as the heavenly bodies do under definable, predictable physical forces, was accomplished in the late nineteenth century but rediscovered in the twentieth. One can now understand why and how like begets like (and also unlike).

The stage was thus set by intellectural Titans of the last century and the actors of the present one have indeed played their role well. Although (aforementioned) Driesch veered to mysticism once again because he thought the blueprint in *toto* can arise *de novo* out of every part of the embryo and this fact defies the laws of science, his view was swept away by an ever-increasing massive body of findings.

In short, hectic activities in the first two or three decades of this century following the lead of Roux, Driesch, Hertwig etc. revealed several clear facts. In one class of embryos (regulation or totipotent) if one part of the embryo (say, one of the first two cells or two of the first four cells) be removed, the remainder can develop into a complete fully formed embryo or, in other words, *each part* is equally powerful to generate the blueprint for the whole animal. Many vertebrates follow this rule. As late as in 1952 Seidel showed this to hold good for the rabbit, a mammal and to-day we know that the human egg, too, is no exception. In the other class, (mosaic) the future pattern seems to have been fixed early, so that parts, if separated, give rise to incomplete embryos. Many invertebrates follow this rule. As late as after 1950 Clement showed that the ordinary pond snail, a mosaic egg, sometimes behaves as if it were not strictly of this type. In 1973 Morril found a very small percentage of these eggs to behave like a regulation or totopetent system. Almost simultaneously

I noticed these dual properties in the common Indian pond snail. My approach was slightly different. Since the third cell division cycle leads the 4-cell embryo into 8 sharply unequal cells, 4 big and 4 large, I addressed the question: if the two cells following the first division cycle are separated by a technique I developed, do they generate small cells after two more divisions or not? In the first case (4 unequal cells, 2 big and 2 small) they would be truly mosaic, in the second case (4 equal cells) they would behave like regulation eggs. We can also reformulate the question- is there a counting device in the cell that can remember the number of divisions ? In my experiments some behaved as regulation and some as mosaic type. Some cells remembered the exact number of divisions even after separation from sister cells, others did not.

It became quite clear after the first two decades of this century that there is no " preformed" blueprint (in the Aristotelian sense) in the early stages of many eggs but nonetheless it is not a question of something arising out of nothingness (epigenesis). The egg cell, to start with, is not homogeneous like a drop of water. Gravity forces some material to the bottom, very specific patterns of cell division lead to unequal distribution of substances some of which could be revealed by particular stains. Child and others raised the concept of initially laid " gradients" in whole organisms and in the egg. Six or seven decades later a molecular basis of such gradients was clearly revealed in Drosophila (fruit fly) egg and embryo. Meanwhile, bustling activities in the field of genetics after the rediscovery of Mendel's Laws made the embryologists acutely conscious of " predetermined" factors of heredity.

Development of an organism from an egg cell is therefore the result of a series of interactions of a set of preformed hereditary factors on a set of preformed gradients in the egg. Thus although there is no preformed blueprint of the body, nonetheless quite well-defined evidence for a more subtle preformation theory has been brought to light.

In 1953 Crick and Watson established the double helix model of DNA, the molecular basis of heredity and in 1961-62

Nirenberg and Ochoa and then many others " cracked the genetic code." Basically, the question now is how special parts of DNA act through another set of molecules (RNA) and produce specific proteins some of which lead to further diversifications ultimately shaping a body out of an egg or, for that matter, keeping the machinery of cells of an adult body running. In 1965 or so, Gross, followed by Spirin and Monroy, created the science of Molecular Embryology, a sub-discipline of chemical embryology fathered by Needham and Brachet. (Limitation of space has forced me to by pass the outstanding contribution of Spemann to classical experimental embryology but this does not prevent us from developing the present conceptual framework.)

From the late sixties the study of biosynthesis of protein and nucleic acid molecules (DNA and RNA) became a very important part of embryology. A general picture in the seventies can be glimpsed in the reviews of Deuchar (vertebrates) and of Brahmachary (invertebrates). My own work, for example, was that in the pond snail maximal RNA synthesis takes place at a certain developmental stage (when the embryo wildly rotates) and the major part of this is a medium-size-class RNA, presumably messenger RNA, transporting messages for major developmental programmes from DNA, the hereditary book written in a special code language deciphered after 1961.

By 1970's it was clear that the main problem of DNA—>RNA —>protein in the course of embryonic development is amenable to known scientific techniques though numerous details await working out. But the question remains, how morphogenesis, the shape of a body, is determined? Why should there be four legs sticking out of the trunk of a dog at four corners or two wings in the frontal part of a chick or fruit fly? In 1980's Nusslein-Vollhard and others began to gain an inkling of the answer. About 30 genes, well defined sequences in DNA molecules, govern the morphogenesis of a fruit fly. So from Roux to Nusslein-Vollhard, from 1888 to 1988 or so we have made an astonishing headway in solving the problems raised by the wisest men in olden times. We now have an understanding of the basic principles of embryology and genetics.

b. Cellular and molecular basis of mind.

During the last two or three decades people like Kandel and Rose and their associates have tried to trace certain learning and /or memory to a very primordial level. They worked on *Aplysia*, a marine shellless snail and the chick, respectively. Certain specific cells and specific chemical and electrical activities such as the synthesis of special proteins (Crebs 1 & Crebs 2) and " firing" (i.e. electric pulse outbursts) in special cells seem to be inextricably associated with simple learning processes or memory. Inhibition of these leads to abolition of the memory and so probably these activities are very pertinent. If a machine is running in a room, the vibrations on the wall or the noise generated do not help us to understand the working of the machine. But the researches mentioned above do not seem to be as superficial as studying the vibration of the wall, rather it looks as though they have been probing parts of the machine itself. Even recently outstanding physiologists like Eccles have expressed the opinion that mind would not be explicable in terms of our sciences. On the other hand, philosophers like Dennett suggest the opposite view. Perhaps the work of Rose and Kandel support the second, materialisic standpoint.

c) Repercussions on the practical world.

Cloning. A spin-off from the quest of pure science as described above that shook the world is cloning. Several years ago Rorvik presented his fiction " In His Image" in the garb of a first hand reportage and was sued. The story is the formation of a human being from the nucleus of an adult cell of a business magnate planted into the enucleated egg cell of a surrogate mother. Whether the nuclei of adult cells are still capable of totipotency if introduced in an enucleated egg cell was a question that embryologists tried to anwser earlier. Wilmut and his group succeeded in " producing" two sheep, Megan and Morag in 1995 which had developed from the nuclei of a 9-day old embryo i.e. partly " diffenentiated" (specialized) nuclei. In 1997 (February) Dolly was born from the nucleus of an adult cell and hit headlines all over the world. A few months later Polly saw the light of day

and this and some other animals were " transgenic" (see later), i.e., they carried a gene of another organism, here a human blood clotting protein gene that might be used for treating haemophila (B form), a genetic disease that prevents clotting of blood. (As a result even a minor injury may turn out to be very dangerous, - one might bleed to death). In December 1998 Kato and colleagues succeeded in creating 8 calves out of 10 attempts and 4 of these 8 survived. In this manner many exact replica can be made out of the most milk yielding cow.

Genetic Engineering. By 1998 about 3 billion units in the sequences of human DNA have been " read". About 5000 human diseases are known to be due to genetic fault, for example, cystic fibrosis is caused by a single wrong amino-acid which itself is due to a mis-sequence in one triplet out of 250,000 units in the DNA sequence. In a genetic lung disease the cause is the lack of production of α-1-antitrypsin. In this case aerosol spray of the right protein (synthetic) could bring some relief to the patient. Such synthesis is facilitated by analysis of the exact sequence of DNA. More than a hundred " Restriction Enzymes" which "cut" the DNA chain at specific points are helpful here. With the help of " reverse transcriptase" - a piece of DNA may be made from RNA. Also Polymerase chain reaction can amplify a small amount of DNA. But after all that the practical problem of introducing the gene into the egg-cell or embryonic cells is difficult but two or three methods (direct injection with a micromanipulator under microscope, through a viral vector, through bombarding of micropellets smeared with DNA) have been tried. Plants and animals carrying such foreign DNA are termed " transgenic". Transgenic bacteria have already produced pure human insulin. Vaccines for man and animals may be obtained in large quantities from trees. Desirable qualities may be introduced into marketable plants and animals through introduction of foreign genes. Possible or imagined dangers of such " engineering" of living things have been discussed and in England many people are against using such genetically engineered or manipulated (GM) food items. Excitement is less in America.

An unfortunate side line is the terminator gene of Monsanto, the largest seed company of the world. The cotton seeds they promote will germinate into plants which themselves will not produce viable seeds. Once a third world country loses the indigenous seed store by large scale switching over to the GM seed, she will be at the mercy of Monsanto.

2. a) ***In the lap of Nature***

Aristotle was an observer of Nature, he went outdoors and watched closely even marine animals in clear, shallow seawater. Later on Natural History, as opposed to pedantic biology, used to be a hobby for many European gentlemen living in the countryside. Gilbert White set such a tradition in England more than two centuries ago and Darwin's outstanding work was possible, for, he had a Naturalist's bent of mind. The rise of Cell Biology and Molecular Biology threatened to smother field work and the science of observing living animals but the second half of this century witnessed an unprecedented degree of activities among field biologists. The so called fierce animals of the tropical countries attracted observers, mostly Anglo-Saxon, like iron filings to magnets and snorkels and scuba opened the door to under-sea exploration.

As " Progress" measured in terms of a technology-based life style destroyed pristine Nature in the third world (the biggest storehouse of Biodiversity, the indigenous wealth) conservation became the first world's burden. Just when Watson of Double Helix of DNA fame denounced taxonomy and ecology as an outdated, unintellectual vocation, Wilson started his crusade for studying and therefore conserving biodiversity. Meanwhile the trio, von Frisch, Tinbergen, and Lorenz shared a Nobel prize, the first for Animal Behaviour (Ethology). Their popular books on the language of bees and mental and social feats in various animals became best sellers and generated keen interest further intensified by TV serials on Nature documentaries.

Enthusiastic lay persons can now gain access to some of the researches of men and women like Schaller, Goodal, Fossey,

Galdikas-Brindamour, Boesch, Rasa, etc. who have undertaken long-term research on wild animals under natural conditions. Discarding myth and extracting first hand information we now know what the lives of tigers, lions, gorillas, chimpanzees etc. are really like. Tool-using and other intelligent behaviour patterns of chimpanzees, supplemented by studies on captive animals enable us to address the questions of mind and morality which so far were the subject for scrutiny by philosophers and priests only. Even the African dwarf mongoose or the fox in Britain offer food for thought when we consider the evolution of human family.

b) From Nature to laboratory

Another trend that has recently developed is bridging the gap between outdoors and laboratory. Wilson, the champion of the anti-Watson group, brought ants to lab in more senses than one. Literally he brought ant colonies from various parts of the world into his Harvard lab and he also initiated the study of ant pheromones (chemical signals) at the molecular level. Quite a few supposed pheromones were now identified chemically, and the pure substances could be tested. One such spectacular demonstration was that of the alarm substance (smell of fear).

An interesting paper published by Spande and his colleagues is relevant in this context. Some of the dendrobatid frogs have deadly venom in their skin. In some parts of the world local people used this venom for the tips of their arrows. These toxins (Decahydroquinolines) may have been derived from frogs' prey. - one species of ants.

Thus the predator draws its own defensive arsenals from the prey (a wonderful fact of Nature) and thereby falls a victim to the rapacity of man. Again, Eisner's group has shown that the female of a species of fire flies lures her victim, a male of another species, and gains defensive chemicals (against spider) from this meal. Food and arms from the same source!

One aspect of my own work has been such a bridge, observing the tiger, first in Nature, then in a good zoo (and also by keeping

pet tiger cubs) followed by laboratory studies requiring very advanced instrumentation. Tigers communicate, besides vocalization, with chemical signals the source of which is a fluid sprayed upwards and backwards. On the one hand a study of thousands of such sprays strengthened the theory that tigers mark their territories, warn others and attract likely suitors with the help of such signals. On the other my colleagues and I have identified, chemically, a score or more of such substances (words or letters of the chemical language of the tiger) one of which is the same molecule which imparts the good aroma to fragrant rice varieties. This is the first known example of this substance occuring in the animal world.

Another line of work is that of bacteria etc. which play a role in improtant phases of life cycles of other organisms. The partial metamorphosis of some marine invertebrates depends on chemical cues from other organisms. Bhattacharya and his colleagues in Calcutta showed that some bacteria residing in the intestine of tadpoles induce metamorphosis into frogs. Perhaps some such bacteria played a role in transforming aquatic creatures into land animals in the course of evolution.

All these investigations described in this sub section may be termed as chemical Ecology or chemical Ethology.

c) ***Science against the back-lash of science*.**

The spectre of a large scale atomic warfare between USA and Russia has almost disappeared but another danger—industrial pollution and destruction of forests—looms large.

All that has been due to the influence of Science. Again, the other side of the coin, scientist-sleuths traced the cause of such curses as Minamata. This is the name of a village of fisherfolk in Japan, also used to designate the disease that struck the villagers in 1960's. Industrial effluent, mercury, was dumped in the water of the adjoining bay and Nature converted it into methyl-mercury, a deadlier poison, that began to accumulate through food chain—microorganisms to small fish to larger fish who eat the smaller fry and took its toll on the fish eaters, crows, cats, and above all

man. People all over the world are now conscious of such scourges and are trying to fight them but technological development in the hands of short-sighted politicians and industrialists has become a real menace towards the end of our century. Man may well destroy the planet by large scale pollution.

3. Work in India

Apart from one or two lines of work mentioned above we may note some important researches carried out in Life Sciences in India to-day. Ramachandran and Sasisekharan attracted attention for their work on structure of biologically important molecules. Siddiqui established a school for studying molecular aspects of taste and smell in Drosophila. Gadgil has left a mark by studying various aspects of ecology and championing the clause of biodiversity in India. Gadagkar has contributed to animal behaviour, principally through his detailed studies on wasps. Chandrasekhar worked on biological clocks, that is, rhythms innate in organisms. Ganeshaiyah and Uma Shankar have addressed questions of sibling conflict and parent-offspring conflict in plants (and animals) while Jhori and Johri, Jr. and Mohan Ram are stalwarts in the field of modern botany. Sukumar studied the ecology of the Indian (Asian) elephant. The above is a partial list of Indian scientists working on modern lines.

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IV - 3

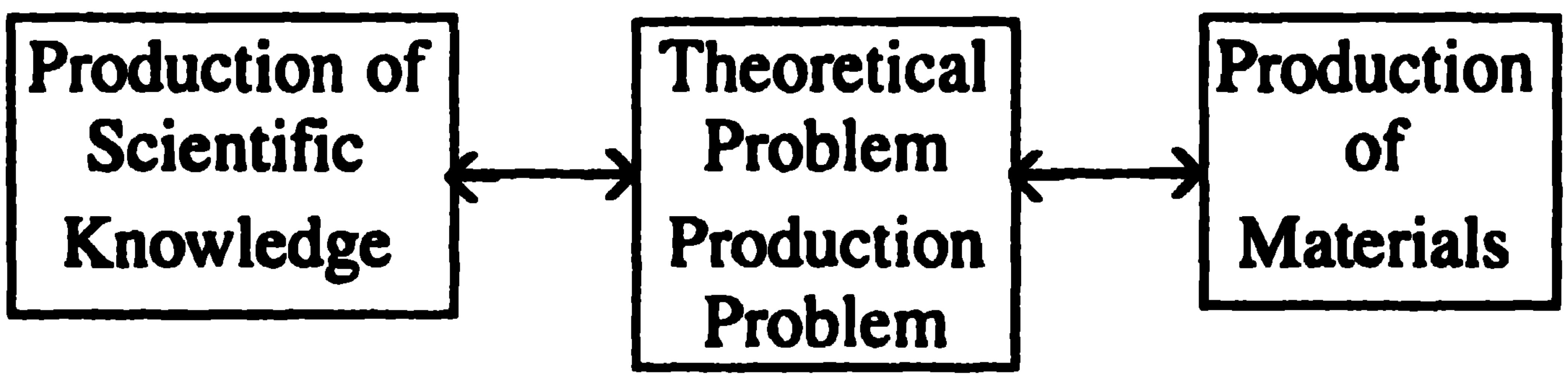
SOME SALIENT FEATURES OF MODERN CHEMISTRY AND THEIR RELEVANCE TO THE SOCIETY

SOMNATH GHOSH

The present topic of discussion consists of two broad issues viz.(i) 'modern chemistry' and (ii)'relevance of chemistry to society.' A brief characterization of them from the stand point of History of Chemistry will presumably facilitate the forthcoming discussion. Consideration of the status of chemisty in the history of evolution of the sciences prompts us to deal with the second issue, viz. 'relevance of chemistry to society', first; and this priority ordering will also be conducive to proper role fixation of the first issue, viz. 'modern chemistry'.

The development of chemistry since the ancient period of human civilization has been propelled by the endeavour to find out a tangible solution to the central problem of this particular branch of human knowledge viz. *to produce substances having a set of desired properties from a host of available natural objects.* Thus, at the very outset, we find that 'Chemistry' is generically, covertly linked to the task of *serving the society* – a bondage which is non-detachable and can only evolve with the evolution of society. This automatically explains the social relevance of this particular discipline, which we continuously experience, consciously or unconsciously, in our every day life.

This central task of chemistry has two distinct aspects which are interlinked through a feed back relation. The first of these two aspects is concerned with the need for *a complete knowledge (commensurate with the level of human culture at any given stage of development of society) of the properties of both the available natural objects as well as of the objects to be prepared, having desired utilitarian properties.* This need has, over the ages, stimulated and directed the entire human theoretical enterprise in chemistry—and thus it has remained the principal domain of study of the *natural philosophers* of the ancient times and of the *scientists* of more modern periods, till date. The second aspect of the central problem of chemistry has always demanded *a comprehensive idea about the actual procedures leading to the transformation from the 'available' to the 'desired'* — and this has generated a plethora of useful and viable technological processes, as well as artifacts and appliances necessary to execute these processes. Thus, this has created a field of activity for magicians and artisans in the antiquity, and for technicians, engineers and technologists in the contemporary era. These two diverse fields of chemical interest are implicitly or explicitly linked through a very essential feed-back relation (these two aspects and their interconnection are schematically presented in the figure 1 below[1]),

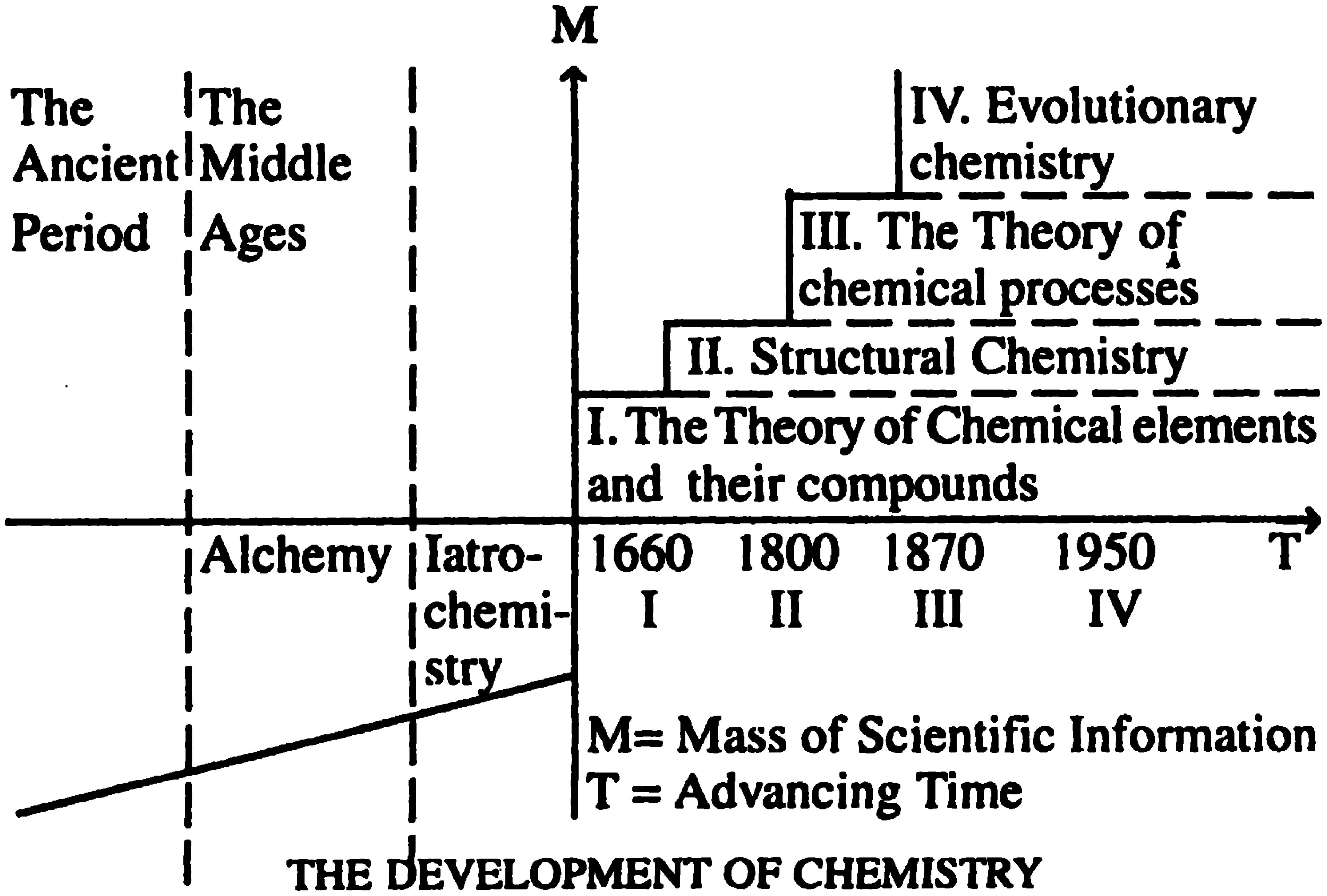


FUNDAMENTAL PROBLEM OF CHEMISTRY
Figure.1 (Reference No. 1, p. 35)

which has served as the main motive force behind the overall development, as well as proliferation into different specialised branches, of chemistry and are also responsible for the 'maturation' of this particular branch of human knowledge, to its present stage of a 'comprehensive science' (in the present/

modern connotation of the term) capable of playing a useful and active role in the social production system.

It has been possible to identify[2] five different, distinct attempts to determine a material solution to this central problem, which have emerged over the ages in the various stages of development of human culture. We prefer to regard these five approaches as, the five, sequentially generated, 'Chemico-Scientific Programmes' with their respective theoretical and techno-practical contents, according to some recent trends of researches in history of science,[3] which effectively resolve the dichotomy between the 'internalist' and 'externalist' approaches towards the problems of history of sciences, in general. According to this model the whole development of chemistry, upto the present age, can be represented in a time graph (where the achievements of chemistry along with the emergence of various scientific programmes has been plotted in a horizontal bar graph against advancing time, the plot is depicted below (Figure 2).



THE DEVELOPMENT OF CHEMISTRY

Figure. 2 (Reference No. 2, p. 43)

Here the year 1661, the year of publication of the celebrated book, 'The Sceptic Chemist'[4] by Robert Boyle, has been

identified as the 'time of birth' of 'Modern Chemistry' from the womb of ancient Alchemy and Iatrochemy (as such, this year acts as the dividing line between the two epochs of Chemistry viz. Ancient and Modern, vide Fig. 2). It is true, as the study of history of chemistry reveals, that the emergence of modern chemistry, in the shape as we find it today or as it was even in the middle of the 19th century, did not emerge right from the pages of the above-mentioned 'rebelious' text of Robert Boyle, wherein he set forth, 'the scientific definition of Chemical Elements (in direct contrast to the 'notion' of the so-called 'sophic general elements : "earth", "air", "water" and "fire") and established on firm grounds 'the principle of experimental verification', advocated by Roger Bacon[5], in Chemistry. On the contrary it had to travel through the labyrinths of the 'Philogiston Theory of Combustion', ultimately emancipating itself through 'the 'discovery' of the correct role of oxygen' in this context, in the hands of Lavoisier, Priestley and others.[6] Nevertheless the ball was set rolling in the right direction by Boyle's monumental work, as is evident from the fact that, while pre-Boyelian Chemistry invented certain useful chemical substances and contrivances, as also some, methods (mostly circuitous), it was essentially engaged in inventing *the ever-illusive process of making of gold from baser metals*, whereas the chemistry of the Boyelian and of the immediale post-Boyelian era could boast of chemists like Agricola, who charted the workings of mining industry in a documentary fashion, and Glauber, who not only credited himself as the inventor or 'Sal mirabiliss' (the well-known Glauber's Salt, Na_2SO_4, $10H_2O$, useful both as a medicine and also as an industrially useful chemical) but also devoted himself in organising and documenting, with diagrams and process details, of several important industrial procedures.[7] Thus, gradually, an atmosphere was created where chemistry could free itself from the bizzare role of a 'black art' and could establish itself as a definitive branch of knowledge, capable of meeting the social demands of a newly emerging, industrial production oriented, capitalist, society through the ensuing industrial revolution.

Modern Chemistry, thus liberated, dwelt upon the inorganic and organic Nature evenly, to produce materials of immediate necessity. An inspection of the schematic progress chart, presented above (Fig.2), reveals that to meet the social demands chemistry had to restructure and orient its own house—which was then full of, haphazardly clubbed, rudimentary, speculative theories and dogmas, having no proper empirical database to support them (vestiges of the old alchemical world dominated by Natural Philosophy) — with properly verifiable theoretical constructs like Atomistic doctrine, laws of Stoichiometry and the principle of Periodic arrangement of, discovered and to be discovered, chemical elements. This was attended by a cautious but firm entry into the wonderland of Organic Chemistry, primarily designed to deal with materials originating from the living world of plants and animals. But right through its development, from the seventeenth century to the last quarter of the nineteenth century, chemistry was principally and faithfully devoted to its main task of *production of materials with preset properties.* With the increasing inter-penetration of Physics and Mathematics into the realm of the theories of Chemistry, it became gradually armed with quantifying abilities and power of abstraction necessary to create a 'break through' into the inner world of 'atoms', so piously declared as, indivisible, discrete, final identities of gross matter, in the Daltonian atomistic principle. Closeness with Physics compelled the chemists of the 19th century, to be more vigilant about the interaction of matter and energy, not only heat energy, but other forms of energy as well, and principally electricity. Thus chemists, for the first time shifted their focus, from matter present in nature and their transformation into desired objects under the influence of heat alone, to a new field of 'matter energy inter-relation'. This not only gave birth to a new branch of Chemistry—the Physical Chemistry—but also paved the way towards a radically different understanding of Nature, viz. the indentity and mutual transformability of 'matter' and 'energy', which took concrete shape at the beginning of the 20th century. Physical Chemistry, through its experimental techniques, more

akin to Physics, and by its zeal to establish quantitatively verifiable physical laws and theories for chemistry, soon exalted itself to the status of 'general or theoretical chemistry', by the end of the nineteenth century. This evolution was really necessary for Chemistry to become a complete Science—in the modern sense—with both 'predictive' and 'productive' capabilities. This transformation of the subject of chemistry was heartily heralded by the emerging social and political force, the burgeosie, which was then gradually consolidating its position both in the post-industrial revolution Europe and in some far-flung colonies.

Actually, if we look at the quantum of achievement of chemistry corresponding to the successive emergence of its second, third and fourth Chemico-Scientific Programmes, we would really appreciate how chemistry was gradually equipping itself to meet the social demands of the corresponding periods. The transition from the manufactory stage of capitalism, with its manual techniques and limited range of the objects of labour, to the factory system of capitalist production, resting on machinery and a new raw-material basis, stimulated the processing of a vast mass of substances of vegetable and animal origin, whose quantitative diversity was astounding, while their composition was extremely uniform. Under these conditions, and also as a result of the discovery of isomerism and polymerism in the early 19th century, there emerged the second conceptual system of chemistry viz. *the Structural Chemistry*[8]—thus, once mainly analytical, chemistry became a chiefly synthetic science. The period in which Structural Chemistry took shape is designated by the historians of chemistry, as the "triumphant march of organic syntheses". Between 1870-1890, chemistry responded to the requirements which sprang from the development of production that had engendered this mode, by producing diverse dyes for the textile industry, various preparations for pharmacy, man-made silk for production and everyday needs, and at the start of the 20th century—synthetic rubber for the first few batches of motor cars. That was a stunnning response on the part of chemistry, because uptil then

all these materials were to be had only in limited quantities and were extracted with vast expenditure of low productive, mainly agricultural, labour.

But, the intensive development of the automobile industry, aviation, power industry and instrument-making in the 20th century, confronted the science of material production with absolutely unusual demads : there was a need for materials with strictly preset properties and, in unprecedented quantities, including : high octane motor fuel, special lubricants, special rubber and plastics, highly stable insulators, heat-resistant organic and inorganic polymers and semiconductors. Structural Chemistry alone was not equal to this task, as : (i) it failed to ensure economically acceptable outputs; (ii) it was oriented upon active original substances of vegetable origin (e.g. alcohols, acids etc.); and, (iii) it was not able to control the process of syntheses. Under the inpact of these new demands of production there emerged the *Third conceptual system of chemistry,* viz. *the Theory of Chemical Processes*[9]. The object of chemistry, in this new mode, was presented as the transformation of substances and not as complete substances as such—and consequently the thrust area of this Science shifted from *the establishment of the structure of molecules* to *organisation of a kinetic system*, in which the molecular structure was only a particular factor. This new system enabled chemical knowledge to be even more effective in practical terms; there were fundametally new potentialities for organic syntheses and new methods for controlling chemical processes which manifested themselves globally through transformation of both object and means of labour. This new approach for solving the fundamental problem of chemistry helped to base the world-wide production of such bulk materials as synthetic rubber, plastics, man-made fibers, detergents, ethyl alcohol and so on, on oil-based raw materials (the so called petro-chemical industries came into being) and, the production of nitrogenous fertilisers upon the nitrogen of air. While in 1935, incidentally, 100% of the materials such as leather, furs, rubber, fibers, detergents, varnish, lacquer, acetic acid and ethyl alcohol were

made from animal and vegetable raw materials, requiring the consumption of tens of millions of tons of grain, potatoes, fats, hides etc., contrarily in the 1960s, cent per cent of industrial alcohol, 90% of varnish and lacquer, 80% of detergents, 65% of rubber, 35% of fibers and nearly 20% of leather materials were being made from gas and oil-based raw materals. Besides, far from requiring the use of agricultural raw materials, Chemistry now started supplying agriculture with hundreds of tons of urea and petroleum protein, only as cattle feed, and hundreds of millions of tons of fertiliser.[10]

But these potentialities were not the limit in any sense. In response to the requirements of the most highly developed mode of production of material wealth so far envisaged, since the beginning of the latter half of the 20th century, Chemistry has started moving towards a new mode of solving its own central problem, through the emergence of its *Fourth conceptual system*, namely, *Evolutionary Chemistry*[11] wherein it has started using the catalytic experience of animate nature itself. This new system has been truely characterized as an 'evolutional' one because, since the issuance of this trend, Chemistry has ceased to remain a *mere supplier of materials with preset properties,* instead, with the knowledge gained about : i) the interior of the atoms of elements, ii) motions of the subatomic particles and their energy resources, iii) the animal and human biochemistry, and so on, it has further *evolved into the Science of Materials*, which is capable of developing peculiar properties at the sub-atomic levels of many naturally available (chemical) substances.

Thus, this mode has started producing : i) *pizeoelectric effects* in quartz crystals which has a direct applicability in modern electronic watches, electrical signal generation in sensitive music systems, etc.; (ii) *ferroelectricity* in certain crystalline compounds such as potassium hydrogen phosphate, barium titanate and so on, which find use in : preparing micro-capacitors of high capacitance, usable in high precision electronic instruments, pyroelectric infra-red detectors for various spectroscopes etc.; (iii) *superconductivity* at quite a high temp.

in some complex metal oxides such as Y $Ba_2Cu_3O_7$ (Yttrium, Barium, Copper Oxide)etc. which possess zero resistance at temp. close to 100^0K, and naturally find application in high voltage power transmission with zero resistance loss and, in preparing efficient magnets as also in the ultra modern, levitation transportation, etc.; (iv) *nuclear reactors,* where nuclear fission reaction occuring in stars is carried out in a controlled condition to produce huge amount of energy — thus, as if, the heat energy employed by the alchemists in their attempts to transmute baser elements to gold is now being rerurned back to nature, in much larger amount, by Modern Chemistry !; (v) *microchips* for the integrated electronic circuitry of modern computers and telecommunication networks, and the like; and (vi) more recently, *metal like crystalline character* in an *amorphous substance like glass* and *conversely glass like transparency in metals*[12] —whose application potential is yet to be ascertained completely. This list of newer and more innovative fields of applicability for this evolving Science of Materials, by no means, comes to an end with these entries and actually we have mentioned here only some of the most astounding items from an ever increasing collection. It is to be remembered that such effects are seldom produced through random empirical exercises, but are achieved through planned experiments with chosen materials, a comprehensive knowledge about whose internal, sub-atomic structures forms the immediate data-base of this newly evolved science, viz. the Science of Materials.

In the ancient times, when Chemistry was essentially a magical, occult art, the contemporary society entrusted it with the task of healing the ailing human beings, and it had performed that duty faithfully, in a more organised fashion in the Orient, especially in India, Arabia and China, and in a less ordered way in the Occidental societies. Practically, the assertion of Roger Bacon, the thirteenth century English alchemist, that medicine should make use of remedies provided by Chemistry[13], and his realization that Chemistry is a Science intermediate between Physics (in Aristotelian sense) and Biology[14] were actualised only through the zealous endeavour of the 16th century doctor-

cum-alchemist, Paracelsus, who declared that the preparation of medicines was to be the only aim of chemistry—thus transforming this gold-making Science of then Europe to an essential handmaid of medicine. The school of, 'Iatrochemy' (Iatros—Greek word, meaning—'*healers*' or '*physicians,*' and 'Chemy'—from Arabic word 'Chemia', *signifying the art of transformation of substances*) was thus founded, and it signalled the gradual decline of the already decadent 'alchemy' on the European soil.[15] From then on, chemistry continued to serve the medical world and its service took a more effective form, with the emergence and establishment of Organic Chemistry, in the beginning of the 19th century. This particular branch of chemical science has, since then, offered many pharmaceutical preparations and medically significant chemical compounds. But, the understanding that chemistry can really form the theoretical basis for the science concerning the living world, namely Biology, was still a distant dream and it remained so even at the beginning of the 20th century.

We have already noted that Physics started influencing the world of chemistry towards the end of the nineteenth century. But this intrusion was not unique. Another neighbour of chemistry in the system of sciences, namely Physiology, made its influence strong enough, to justify the establishment of another new branch of chemistry, the biological chemistry, Biochemistry parallel to physical chemistry. Among the four branches of chemistry established before the dawn of the 20th century, viz. Inorganic, Organic. Physical and Bio-chemistry, the last one has a special position at the borderline of Physiology and Medicine and this peculiar status of this branch even poses practical problems for the Nobel Prize Committee in deciding in which field to place the work deemed for deserving of a prize. But greater were the conceptual difficulties when Biochemistry was burdened with the task of providing a "complete and exclusive explanation" of life. Hans. A. Krebs, expressed this difficulty with special reference to the study of carbohydrate oxidation, a basic process in respiration and muscular acitivity, which we try to explain by intermediate chemical reactions[16]—the reaction sequence being now referred to as 'Krebs Cycle' :

"Physiologically, most intermediates exist only transitorily, i.e., in minute quantities. Moreover they only occur intracellularly. These circumstances, preclude their identification under "physiological" conditions .... The statement, therefore, that the evidence is valid for living tissues under "physiological" conditions always implies the assumption that reactions occur under conditions different from experiment. As far as one can see, this state of affairs is bound to persist, and for this reason the theory of intermediary reaction mechanism is bound always to remain a theory."[17]

And the inadequacy of the very approach, that Bio-chemistry is just chemistry for the biological systems and not a new branch of science endeavouring to unravel the real mystries of life of different forms—from intellectual mamnals to small microbes—with the theoretical insight and system developed by chemistry from its study of the non-living world, is implied in the words of Albert Szent-Györgi—"There is no doubt in the authors' mind that the real nature of life will remain a closed book as long as we try to approach it only with ideas of "Classical Chemistry".[18]

The science of the chemistry of life did not penetrate the "secret" of life, until the middle of the 20th century through the works of Watson and Crick when they identified and established the structure of the basic chemical entity of hereditary funciton namely 'Deoxy Ribonucleic Acid' (DNA).[19] That in a sense actualized the dream of Karl Marx along with the practising early biochemists of his times at the dawn of this discipline : "............ According to them the cell has been abandoned as the primeval form; instead a formless but contractile particle of albumen is taken as "starting point" .... The primaeval form must naturally be traced down to the point at which it may be produced chemically. And it appears that the way to this point has been found."[20] (Here Marx was refering to the unusual phosphorus compound, 'nuclein' isolated from pus cells in 1869 and also to certain complex phosphorus containing acid materials isolated from different kinds of cells and termed 'nucleic acids' as they were found to be chemically similar to neclein.[21])

Though there is much more to life than mere Chemistry but there is a part of life that can be grasped by chemical means, and there are chemically defined substances that can change the course of essential processes in living organisms. Directing their investigation to such areas, biochemists discovered new facts about nutrition, about substances essential for health, and about medicines and medications.

In 1897 Christian Eijkman in Java, found that hens kept on a diet of polished rice developed a paralysis similar to that of 'beriberi' and they could be cured by adding the rice polishings back to their diet. Eijkman suspected that polished rice contained some poison which was counter-acted by the added bran. But soon it was proved wrong and it was established by Wildiers in 1910 that the disease was caused by a deficiency in the diet and not by any poisonous bacteria—actually the unavailability of some beneficial substances present in the bran was responsible for beriberi—and Wildier termed this factor 'bios".[22]

Similarly, calories and the chemically known components of food had to contain certain mysterious "factor" in order to maintain the normal rate of life—not quantities but unknown qualities seemed to be required. Casimir Funk, in 1912, designated them as 'vitamines'. But they were not 'amines' in the chemical meaning of the word, as they were not alkaline. Jack Cecil Drummond in 1920 therefore suggested the name "Vitamin" to indicate "a neutral substance of undefined composition". In the same way that Berzelius concluded from the knowledge of one ferments that thousands would be found, the bio-chemist expected and gradually isolated not one but a number of Vitamins and Elmen. V. McCollum proposed to designate the sequence of discovered Vitamins alphabetically beginning with first investigated, fat-soluble one, as Vitamin A, the "anti-neuritic (neurities, or nervous deterioration, resisting) vitamin" as 'Vitamin B', and so on.[23]

When Pasteur and Joubert observed in 1877 that the growth of anthrax Bacillus was inhibited by infections with air-borne microorganisms, they felt that this indicated some therapeutic

possibilities. Fifty years later, Alexander Fleming found that a staphylococcal culture, accidentally infected by spores of a species of Penicillum, showed signs of dissolution : "................ I was always on the look-out for new bacterial inhibitors, and when I noticed on a culture plate that staphylococcal colonies in the neighbourhood of a mold had 'faded away', I was sufficiently interested in the anti-bacterial substance produced by the mold to pursue the subject".[23] Raistrick and Thom identified the species as 'Penicillim notatum', first described in 1911, by R. Wrestting. Around 1940, Florey and Boris Chain of Oxford, extracted penicillin from larger cultures and successfully treated patients.

Fleming cured a patient, a middle-aged man, suffering from streptococcul meningitis who appeared to be dying inspite of sulfonamide treatment, by treating him with penicillin supplied to him by Florey and : .... "The result was so dramatic", according to the account given by Fleming,[24] "that penicillin was brought to the attention of the Minister of Supply, who immediately called a meeting of everyone interested, academic and industrial. This became the 'Penicillin Committee", under the Presidency of Sir Henry Dab, which exchanged information freely with the American authorities". Thus the era of 'antibiotics' began. It was reasonable to assume that the production of antibiotics was not the exclusive privilege of a 'Penicillium'. A world-wide search for 'molds' began, and sometimes a successful producer was discovered right in the soil of the backyard or on a molded patch of a piece of melon. A 'Streptomyces' named 'venezuelae', because it came from a mulched field some where in Venezuela, produced a peculiar, Chlorine containing "chloromycin" or Chloramphenicol, a derivative of nitrobenzene. From another type of 'Streptomyces', "terramycin" or Oxytetracyclin was isolated. Waksman developed from a Streptomyces' grisens, 'Streptomycin', in early 1940's, which proved particularly valuable through its wide spectrum of antibiotic action.[25]

The number of microbially produced antibiotics has since then been continually increasing, concurrent with improvements

in the techniques for isolating special strains, creating conditions favourable for their growth and combining methods for producing the antibiotics in high purity. Though the great variety in their chemical structure precluded a theoretical generalization but the time was ripe for industrial production of these antibiotics and their increasingly wide application. In 1953 the production of antibiotics for medical and agricultural uses was 1.63×10^6 pounds with a sales value of $ 231 million, included were 372 trillion units of penicillin salts. The corresponding figures for 1964 were 6.5×10^6 pounds at $ 386 million and 1.202 trillion units.[26] And by the end of twentieth century it has become just a houseold drug in India for bacterial infections and is even administered without the prescription of a doctor—such has been the invasion of the antibiotics in public life!

Exactly one hundred years after F.M.X. Bichats' publication claiming that all physiological processes are directly caused, without any intermediaries, by the tissues of the organism, a decisive experiment by Bayliss and Starling in 1902 in Oxford proved that nerves can be by-passed in exciting the pancreas gland to secrete its juice into blood stream. The substance extracted by them by acid digestion of mucous intestinal membrane acted directly on the pancreas gland. In the way in which Berzelius had established the general concept of catalysis, Bayliss and Starling, in 1904, introduced "hormones" (from the Greek word 'hormon' meaning, "awakening" or "inducing") as the designation for substances in the juices of inner secretion. The first chemically known (i.e. structure established) hormone during this period was the substance isolated from the glands adjoining the Kidneys, the adrenals, and was therefore called "adrenalin". The effect of adrenalin (also called epinephrine) is to increase the excretion of glucose in the urine, as it occurs in diabetes. A structure in the pancreas, "*islets*" (*Inseln*), as Langerhans had called them (1869), were assumed to play a prominant part in this function of the gland. Efforts to extract the active substance were vitiated by a protein-splitting enzyme, *trypsin*. Finally Banting and Best overcame this enzyme action and succeeded in extracting a pure hormone, '*insulin*', and

showed its efficiency in regulating the sugar utilization in diabetes. Again, the pituitary gland excretes hormones which are antagonistic to insulin—injection of pituitary extracts causes diabetes by destroying the pancreas. The chemical basis for these hormone actions is the influence on the formation of *hexose phosphate*, which is the first step in sugar conversion in digestion as well as fermentation, as established by Cori et al. Japanese mycologists and bio-chemists had for many years been interested in phyto-hormones produced by fungi. From '*Gibberella fujikuroi*', a fungus growing on rice, E. Kurosawa in 1926 and T. Yabuta in 1939, developed extracts containing hormones of great growth-promoting activities, *the group of gibberelins*. These fungi produce hormones and poisons together and the applications of too much growth hormone can itself act as a poison for the plant.

Now, whether a substance is detrimental or beneficial may depend on the relative quantity that is administered to an organism. Paracelsus employed alkaloids and mercury salts for successful medications, while a growth promoting substance like 2, 4-dichloro phenoxyacetic acid becomes a weed killer when "too much" of it is applied. Vitamin D was the first substance for which the excess was found to have the opposite of the desired effect. Extremely small quantities of biotic and antibiotic substances exert great biological influence. These substances belong to widely different groups with respect to chemical structure and their effect on organisms. It has therefore proved impossible to arrive at a general theory. Whenever the attempt was made to reduce the explanation to simple physicochemical relationships, it was soon found that at best a preliminary and limited rule had been obtained. Actually, reactions between chemicals remain in the realm of substances while the effect is produced by stimulating a complex of biological processes.

This gap between the theoretical approach of biochemistry and the real happenings inside the living systems continued right upto the 60's of the 20th century when discoveries regarding

structures of nucleic acids and the gradual construction of the biochemical theories of molecular genetics and molecular biology, ably supported by the observational results provided by certain very convincing experimental techniques, like X-ray Crystallography, Electron Microscopy, Radioisotope labelling etc., generated a firm theoretical edifice for the whole biological science, in general. This evolution of biochemistry to molecular biology revolutionised the entire approach of chemistry to solve the problems of the living world. Instead of just envisaging the biological utility of certain organic compounds, or, identifying the real chemically active principle behind any observed metabolic activity in a living system, it started tackling the problems right from the genetic level through genetic mutation control, genetic engineering, gene monitored biosynthesis of specific proteins, hormones etc. This in turn has started revolutionising the very world of medicinal science altogether: problem of finding out the proper medicinal antidote for the disease concerned, being gradually replaced by the problem of search for a method of alleviating the disease-producing metabolic imbalance at the enzymatic or hormonal level through proper control of the appropriate genes. Although these efforts are still in their infancy and is essentially limited to the stage of mainly laboratory experiments and that too, only in certain highly developed countries with sound economic reserves, we can really hope that these facilities will be available to the mankind in general, globally, in no time. In the mean time production of genetic replica of mammals, of the order of a sheep, entirely in laboratory, by the sophisticated "gene cloning" technique has heated up things unduly even in the so-called 'scientifically advanced countries' like America and Great Britain. The so-called "liberal governments" of these countries are excercising bureaucratic control over the freedom of scientific investigations under the veil of ethical and moral issues, which reminds us immediately of the black days of control of Church over Science during the middle ages in Europe. In this context another aspect of the medicinal therapies prevalent in the present day society needs a mention here in the

background of the highly advanced genetic techniques developed over the past few decades. That is, 'Homoeopathy',— a system of curing human ailments based on the principle of *Simil Similibus Curantum* ('like cures like')—propounded by the legendary Hahneman, where an insignificant amount of the medicine administered to the sick is "believed" to perform the healing trick. But this issue has continued to remain in the realm of a 'faith', generally attached with a religious practice, rather than in the sphere of some scientific enquiry based on rigorous logic supported by experimental evidences. Molecular Geneticists and Molecular Biologists should try to change this situation by taking a serious attempt to expose the myth, if any, connected with this particular mode of medicinal therapy rather than allowing it to perpetuate as a form of treatment, which is less expensive and as such affordable by a larger section of the humanity and has 'less harmful' side effects.

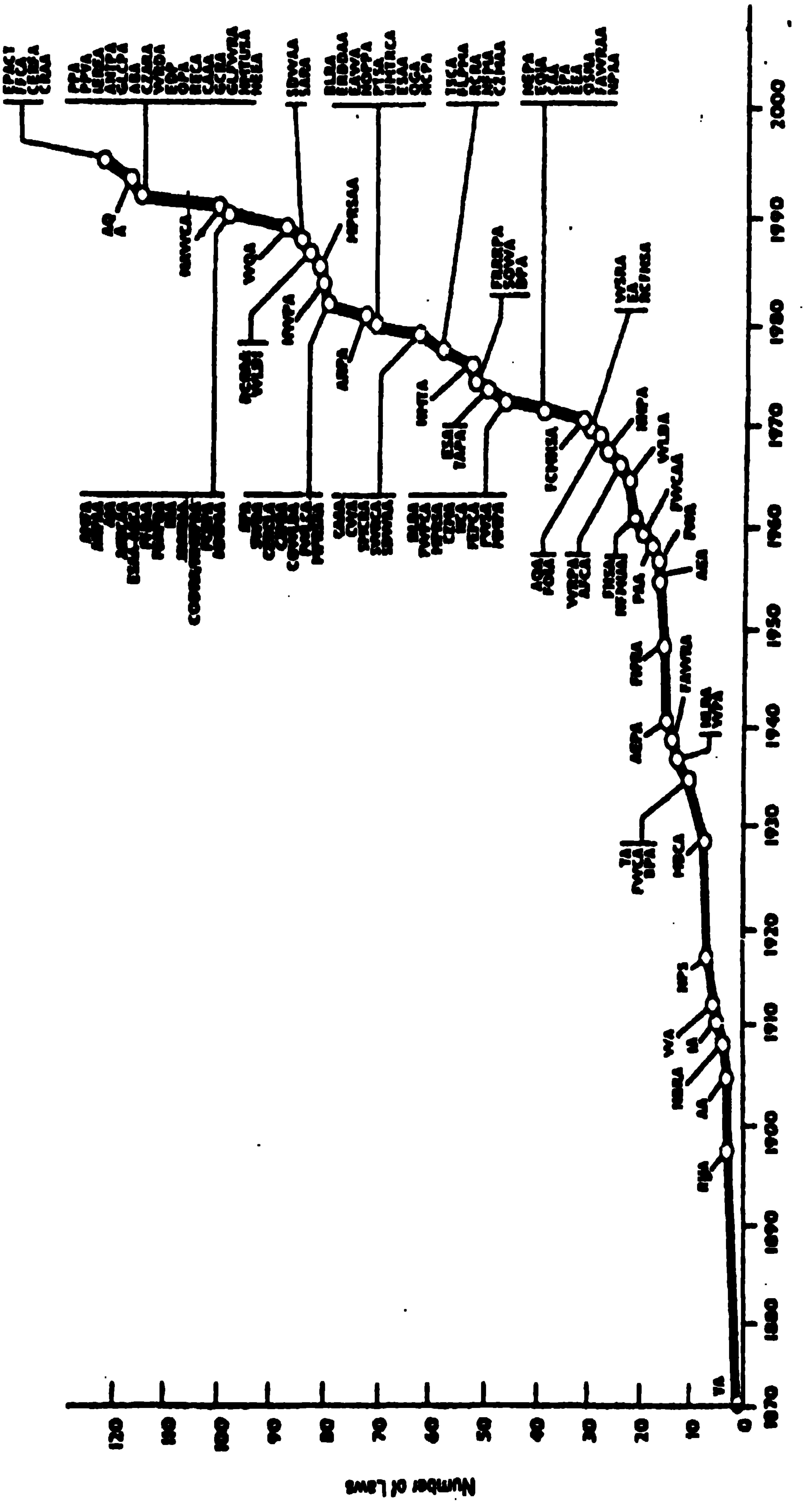
From the foreoging discussions as also from our day-to-day experience it definitely transpires that the discovery and invention of new substances, which is at the heart of chemistry, have proved to be the key-stone for the improvement and well-being of mankind and no aspect of the human existence, from the bare essentials of life i.e. food, clothing, shelter, health, etc., to the luxuries of life, like automobiles and electronic devices (television, computers etc.), has remained untouched by the developments in chemistry. The discovery of antibiotics, vaccines, and other modern medicines (like, life saving drugs) have contributed not only to the extension of human life span by 25 to 30 years since the passage of 19th to 20th century, but also to the upgradation of the quality of human health. The development of effective fertilizers and pesticides have allowed crops to be grown and harvested in surplus quantities. Personal quality of life has benefited enormously through the development of polymer products, material science, and advanced electronics. Thus, as the 'central', 'creative' and 'useful' science, Chemistry and its practitioners have been both directly and indirectly involved in most of the technical achievments that characterize the by-gone century.

But manufacture, processing, use and disposal of many of these highly beneficial chemical products have had a negative impact on human health and environment. Some of the more notable environmental events that have occurred in the past can also assist us in illustrating the negative impacts that chemical activity can have on human health and the environment and the reasons for the present world-wide concerns over the use of hazardous chemicals and their risk to human health and environment. The identification of the damaging ecological effects of the pesticide DDT on avian species by Rachel Carlson in her book 'Silent Spring'[27], is considered by many to be the beginning of the modern environmental movement. The rampant water and air pollution during the 1960s and 1970s, fuelled by such events as the Cuyahoga River (Ohio) catching on fire, further galvanized the environmental movement in pursuit of identifying the hazardous properties of chemicals and their effects on human health and the enviornment. Other events, such as Times Beach (Missouri) and Love Canal (New York) where whole communities were declared unlivable when hazardous substances were found in the solid at unacceptable levels, brought the fear of the dangers of chemicals and their hazards into peoples homes. The catastrophic chemical accident in Bhopal, India, illustrated that, negligence or ignorance were not the only cause of hazardous chemicals finding their way into the environment—the accidental release of hazardous chemicals was also a very real possibility and a source of significant concern. These environmental incidents have, over the past thirty years, shaped the public's opinion about chemicals and their effects on the environment to a point where there is a genuine belief among the general public that all chemicals are toxic or otherwise hazardous, which echoes the saying of Paracelcus : "Everything is a poison, depending on dose". The reality, of course, is that chemicals make up all matter, from lethal to innocuous, but this has little meaning to the vast majority of the populace. It is because of this perception, that chemistry and chemicals are viewed with increasing concern and suspicion by society.

These environmental incidents have also motivated the public as a whole to take steps through legislation and regulation to address the source of these incidents and to make sure that such events cannot and will not happen again. Figure-3 below shows that from the late 1800s through the 1950s less than 20 environmental laws had been passed in the U.S.A.[28], whereas by 1995 over 120 environmental laws were in place.

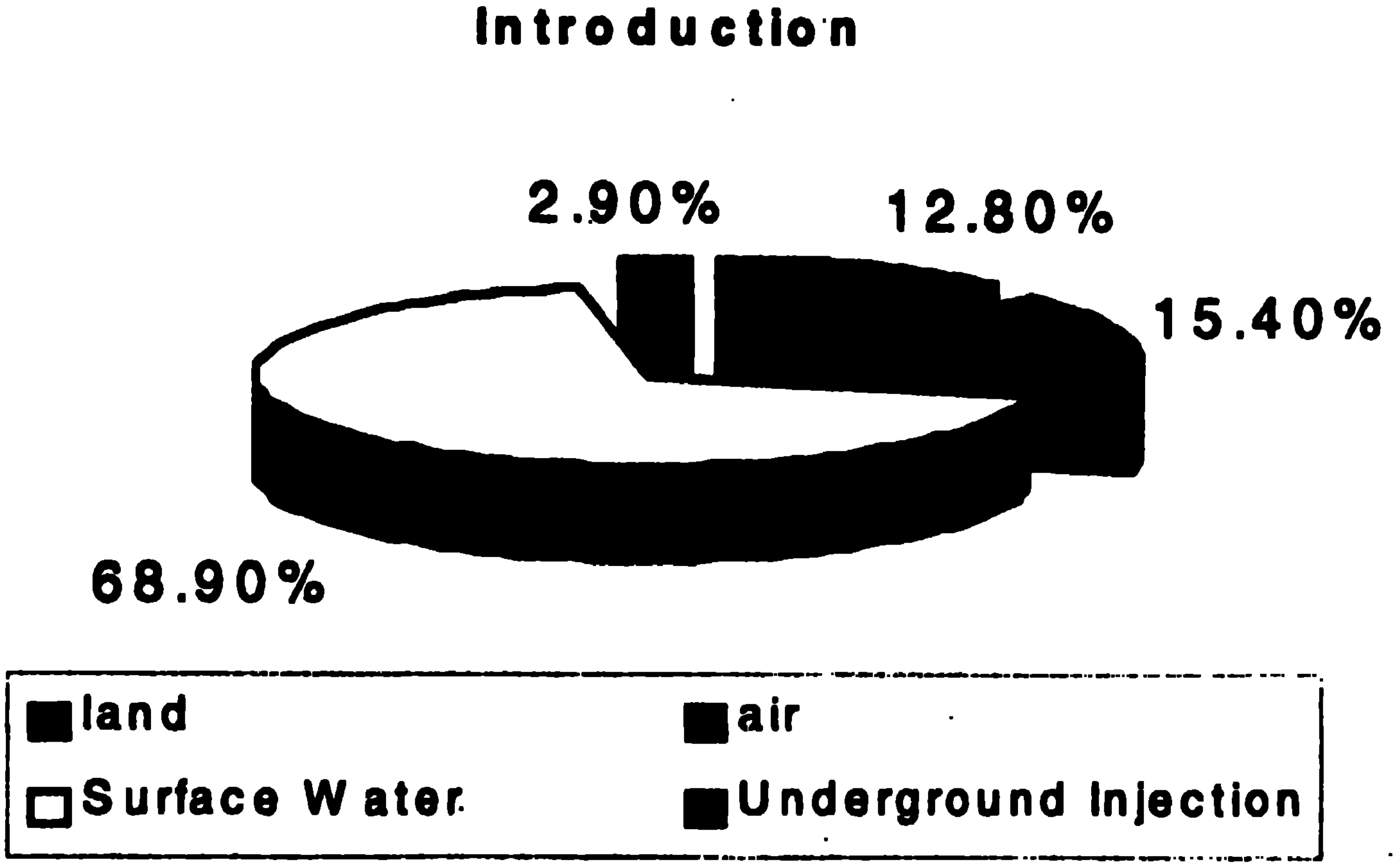
Despite the proliferation of environmental regulations during the past several decades, hazardous chemicals are still being released to the environment in significant quantities. The reason is that, with the exception of the Pollution Prevention Act (PPA) of 1990 all of the national laws passed in U.S.A. allowed for a "command and control" approach for dealing with environmental problems, i.e. acting on problems after they have already happened (the so-called "end of pipe control") rather than preventing them from happening. In 1994, more than 2 billion pounds of hazardous chemicals were released to air, water, and land by over 22,000 reporting facilities as tracked by section 313 of the Emergency Planning and Community Right to know Act (EPCRA)[29] (See. the Pi-diagram, in Fig. 4, below where TRI stands for Toxic Release Inventory). In addition, reporting facilities transferred almost 4 billion pounds of these chemicals in waste to off-site locations for recycling and remediation activities including energy recovery, treatment and disposal (Vide Figs. 5 and 6 below).

In this way, the costs complying with the regulations that deal environmental problems through remediation activites (i.e. waste treatment, control, and disposal costs) rather than prevention activities has been estimated to be in the range of 100 to 150 billion US dollar per year for industry in the U.S.A. alone. In addition, the costs of cleaning up existing hazardous waste sites, are estimated also to be in the hundreds of dollars range. Hence it is clear that the 'command and control' approach that has defined environmental protection for so many decades is not sustainable. Economically, costs associated with remediation activities must be reduced and reclaimed for use in

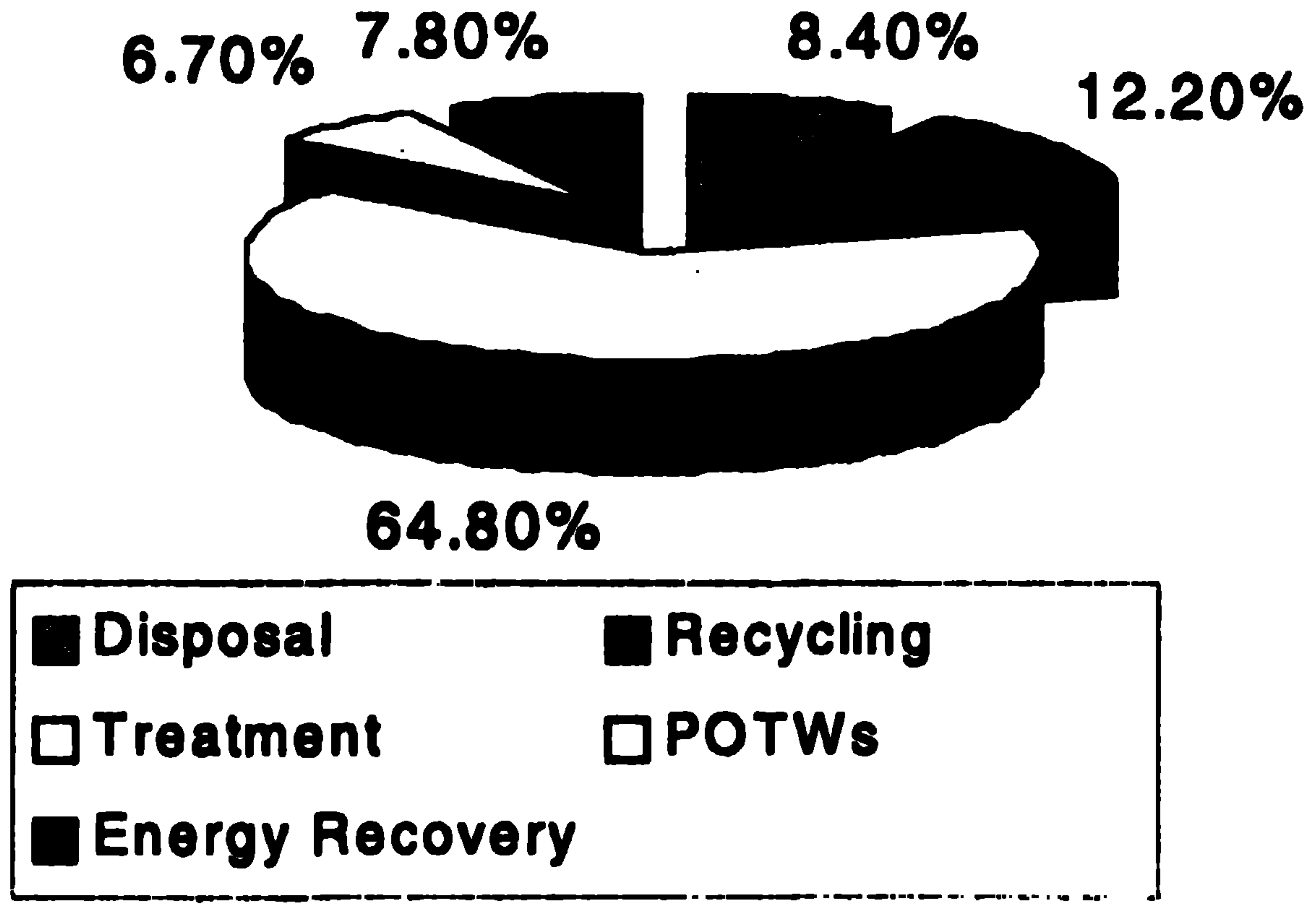


PROLIFERATION OF ENVIRONMENTAL LAWS AND REGULATIONS

Figure. 3

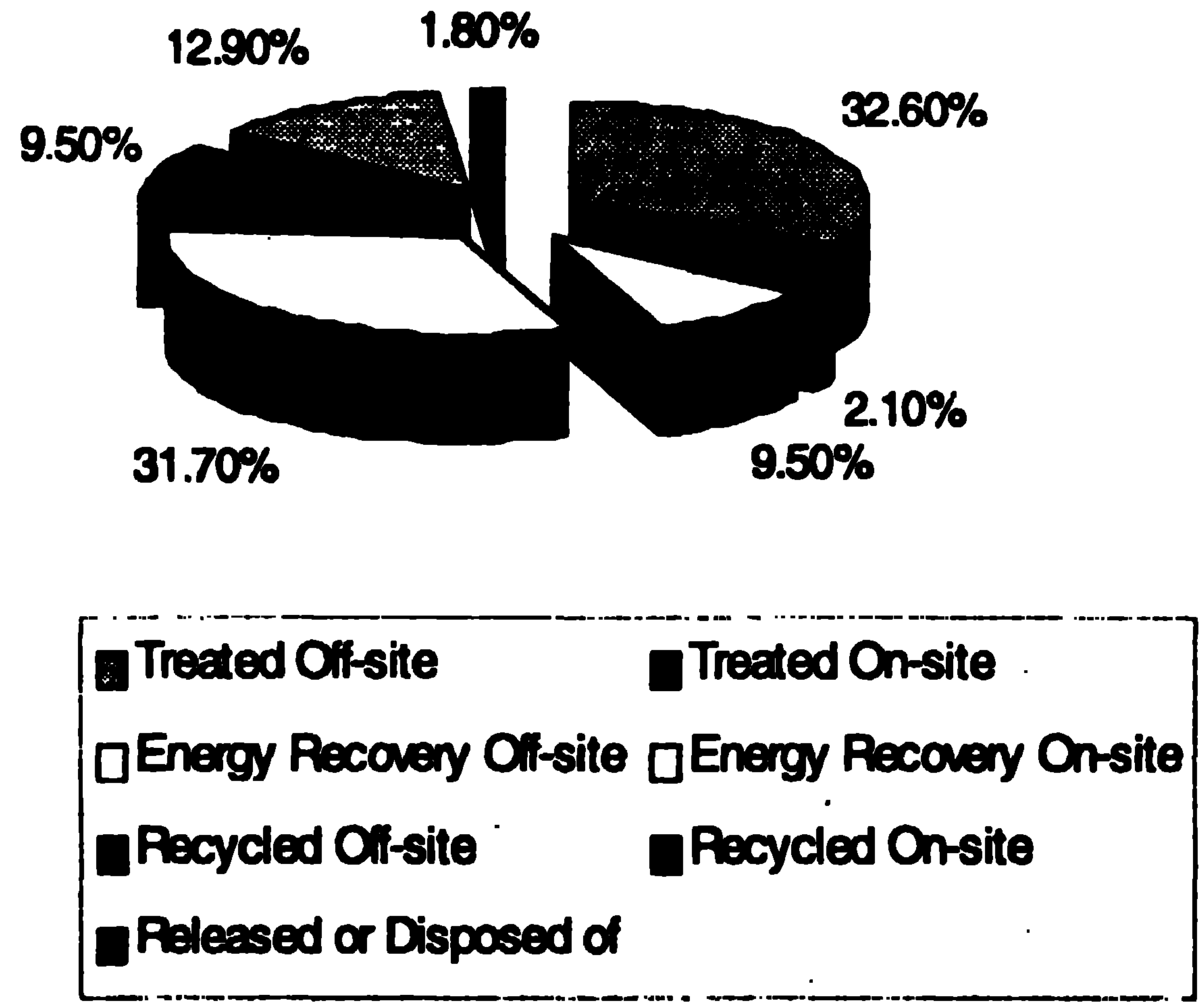


DISTRIBUTION OF TRI CHEMICAL RELEASES TO THE ENVIRONMENT IN 1994.
Figure. 4



DISTRIBUTION OF TRI CHEMICAL TRANSFERS (OFF-SITE) IN 1994.
Figure. 5

the research and development of the substances and methodologies that will be needed in support of future technologies and to enhance quality of life. Environmentally, it is essential that the chemical sciences and industries must also



QUANTITIES OF TRI CHEMICALS MANAGED IN WASTE
(ON AND OFF-SITE) IN 1994
Figure. 6

proceed in a manner that does not continue to cause harm to human health and damage to the environment. Socially, it is imperative that the populace become aware of the innocuous and even beneficial chemicals that have been manufactured and used, and that chemicals can be designed to be both safe and effacious. To achieve these goals the science of chemistry has undergone an evolution in this direction to a new environmentally benign discipline, called 'Green Chemistry', which has developed rapidly since its introdution in the early 1990.[30]

Keeping in mind the fact that chemists as architects of matter have in their power the ability to design products and processes that possess the properties they desire, Green Chemistry simply states that a *central property or performance criterion of any chemical activity must be, that it is benign to human health and the environment.* This is a very simple yet global view of how the field of chemistry should be perceived and practised. Of

course, no chemical activity is ever completely innocuous or totally benign to human health and the environment, but striving toward nothing less than perfection ensures that improvements will always be sought in each step of the process.

The goal of Green Chemistry is to reduce the hazards associated with products and processes that are essential to maintain the quality of life achieved by society through chemistry and also to advance the technological achievements of chemistry. Throughout the evolution of the environmental movement, environmental policies, laws and regulations have focussed on quantifying the risk posed by chemicals in the environment. At its most basic level, risk can be described by the following formula.[31]

RISK = f (hazard, exposure), where f = 'function of'

Historically, environmental laws and regulations have almost universally attempted to *minimize the risk by minimizing the exposure to a hazardous chemical substance*, by controlling the concentrations of a chemical in an aqueous waste stream before release to a particular water body, using scrubbers on the end of smoke stacks to reduce emissions to air, or requiring the use of personal protective equipment such as respiratar and gloves which are all *end-of-pipe control* measures. On the contrary, the *green chemistry seeks to reduce or eliminate the risk associated with chemical activity by reducing or eliminating the hazard side of the risk equation, shown above, thereby obviating the need for exposure controls and, more importantly, preventing environmental incidents from ever occurring through accident.* If a substance poses no significant hazard, then it cannot pose a significant risk, and there is no need to limit the exposure to the chemical substance. The hazard includes : in adition to acute and chronic toxicity, carcinogenicity, and mutagenicity, properties such as explosivity, flammability and corrosivity, direct ecological impacts, such as plant and animal toxicity and atmospheric damage, and indirect ecological impacts such as resource depletion, global climate change and persistence in the environment.

The goal stated above is achieved in the green chemical methods by the use of :[32]

1. *Alternative feedstocks or starting materials*

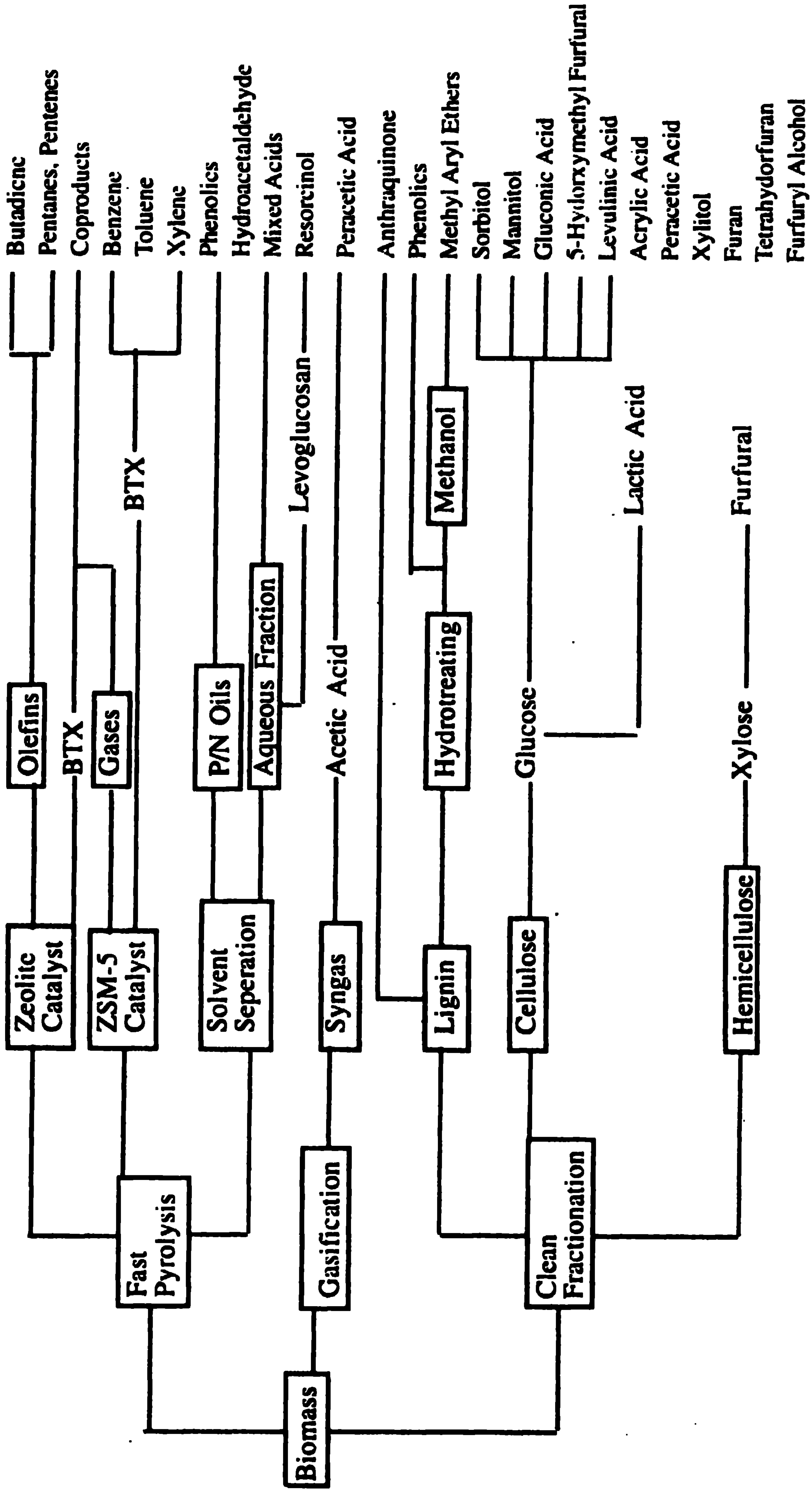
In general, agricultural and biological feedstocks can be excellent alternative feed stocks since most of them are *already highly oxygenated* and so their use in place of petroleum feedstocks eliminates the need for the polluting oxygenation step (vide Figures 7 and 8 below). Other classes of alternative feedstocks are also emerging where visible light replaces the heavy metals often used in petroleum oxidation processes and they are quite toxic and carcinogenic.

2. *Alternative Reagents*

The transformations have to be evaluated to determine whether they are stoichiometric or catalytic, atom-economical or not, and what the characteristics of any wastes that will be generated through the use of the reagent, will be. The catalytic reactions offer some striking advantages over typical stoichiometric reagents because catalysts facilitate a transformation that is desired without being consumed as part of the reaction and without being incorporated in the final product.

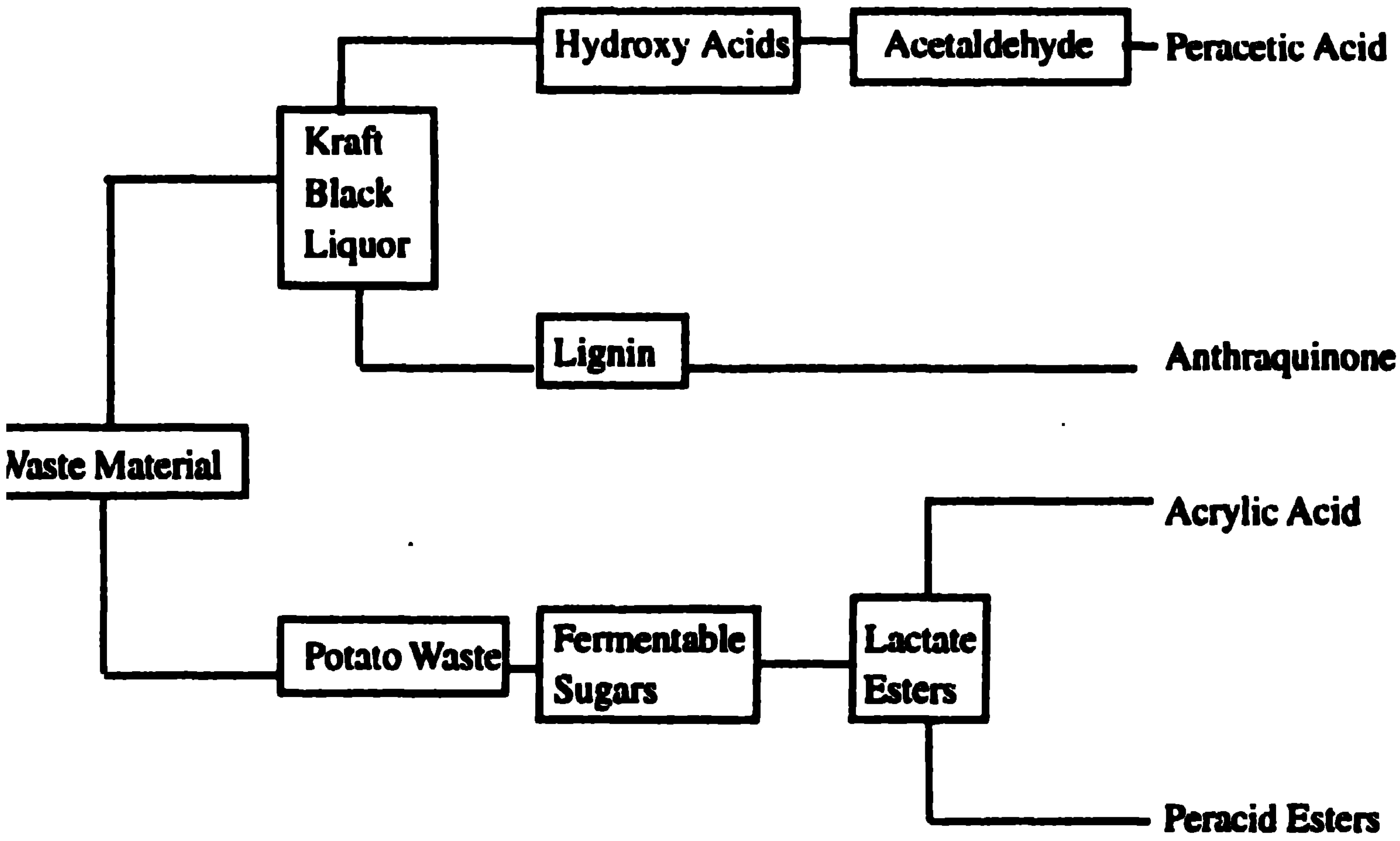
3. *Alternative Solvents*

An important area of green chemistry investigations has centered around the selection of a medium to carry out a synthetic transformation. Many of the solvents commonly used are some of the volatile organic compounds known to cause smog when released to air. Research is being conducted to discover ways to conduct the same kind of reactions in various solventless systems. In certain cases alternatives such as aqueous systems, ionic liquids, immobilized solvents, dendrimers and amphiphilic star polymers and super critical fluids (which are gases at a combination of high pressure and low temperature when they offer certain environmental benefits — a good example is CO_2, which is currently used for providing solvation for variety of chemical reactions as super-critical fluids).



BIOLOGICAL FEEDSTOCKS

Figure. 7



AGRICULTURAL FEEDSTOCKS

Figure. 8

4. *Alternative Product/Target Molecule*

In designing safer chemicals, one identifies the undesirable, toxic portion of a molecule (through toxicological research) and lessens or eliminates its toxicity while maintaining the function of the molecule (through chemical research it is possible to give the product or target molecule the desired function) to allow it to serve a specific, desired use.

5. *Process Analytical Chemistry*

By process analytical chemistry we mean real time measurement of reaction conditions during chemical synthesis coupled with ability to alter the reaction depending on the outcome of the analyses. If 'X' is a pollutant being generated in a reaction in trace amounts but is formed in larger amounts if the temperature and pressure become too high then by using process analytical chemistry one could measure the concentration of pollutant 'X', constantly, during a reaction, and immediately change the reaction conditions if the amount of 'X' becomes unacceptably high. This technique is particularly applicable to biotechnological synthesis.

6. *Alternative Catalysts*

Through the use of new catalysts. chemists are finding ways of removing the need for large quantities of reagents that would otherwise have been needed to carry out the transformations, and would ultimately have contributed to the waste stream. Among the various classes of catalysts the heavy metal based catalysts are often extremely toxic and the same are replaced by effective bio-catalysts in green chemistry.

The exposure that has been presented above is only an overview of Green Chemical Methods, its aims, objectives and procedure—details of it are in the making. This newly developed discipline is applicable to all areas of chemistry and chemical industry providing both enviornmental and economic benefits. Just as chemistry has always been a journey rather than a conclusion, green chemistry is also based on the premise that continual improvement, discovery and innovation is the path towards the perfect goal of environmentally benign. There are, however, some latest areas of research that pose both a scientific challenge to chemists and have also formulated the future trends in Green Chemistry. These are : (i) Oxidation reagents and catalysts, (ii) Biomimetic, multifunctional reagents, (iii) Combinatorial Green chemistry, (iv) Proliferation of solventless reactions, (v) Energy focus, and (vi) Non covalent derivization, to mention a few important ones only.[33]

We conclude our discussion by noting the significant fact that among all the natural sciences, Chemistry is the first to attain the proper 'maturity' so as to recognize the importance of Nature in its totality including both its human and non-human components, and to evolve appropriately to design methods which are benign and beneficial to the whole Nature and not to man alone. Thus, reaching the last decade of the twentieth century the 'Modern Chemistry has started leading us to the all important realization, first enunciated by Karl Marx : " Natural science will in time incorporate into itself the science of man, just as the science of man will incorporate into itself 'natural science' : there will be 'one' science'.[34]

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IV - 4

THE EMERGENCE OF THE *BODY*
(An essay in the history of Medical Knowledge)

ANIRBAN DAS

.... [T]he question : "What is the matter with you?" With which the 18th Century dialogue betwen doctor and patient began, was replaced by that other question : "Where does it hurt?"— Foucault.

I

In this essay I will try to introduce the reader to some themes in the history of the body. Specifically, I deal with the uniqueness of the knowledge of the body as it is known to modern medicine. I do not propose a new thesis. Instead, I summarize certain notions about the emergence of the human body as *the object of medical knowledge,* somewhere around the end of the eighteenth century in Europe. My contention, along with one strand of the theories on the issue, is that this emergence of the *body* as an object of knowledge did in its turn structure the whole corpus of the knowledge of medicine in a specific direction. In other words, the emergence of the *modern* knowledge of medicine had as one of its foundational moments, the birth of a new object of knowledge —*the three dimensional space of the body owned by an individual.*

This essay does not present a straightforward history of events. It deals with the history of a concept — the concept of the human body. Historians have repeatedly pointed out the invisible errors that creep in when a specific concept is treated *ahistorically* in the practice of history writing — is the *body* the same when it is referred to by Aristotle, Caraka, Aquinas, Paracelsus, and a modern doctor. I cannot in this short span, give even a rudimentary inkling of the complexities involved. Instead, I try to trace a few of the conceptual specificities of the body as it is known to modern medicine. That I hope, could give some idea of the difficulties and the attractions that await a historian in her/his art of questioning the past and the present.

Today's academia is not silent on the body, nor on medicine. There is a vast range of literature in the disciplines of sociology, anthropology, history and philosophy dealing with these issues. Canguilhem in his path-breaking work (Canguilhem, 1978) problematized the concept of the healthy body and a purely 'objective' pathology, focussing on the shifting relations of an organism with a changing environment. A barely articulate stress on the phenomenological aspect of the experience of living underlies this project. Subsequent literature have dealt with multiple aspects of the problem. Phenomenologies of the body have been written by Merleau-Ponty (Merleau-Ponty, 1996), Sartre (Sartre 1956) and in a slightly different perspective, by Gadamer (Gadamer, 1998). There are anthropologies of pain, of disease experiences of the community of doctors (Das 1995, Kleinman 1988, 1995, Lindenbaum and Lock 1993, Scambler and Higgs 1998). Studies dealing with history of medical institutions and medical practices have come up, mostly in the West. History of the coming and the subsequent dominance of modern medicine, along with the changing patterns of medical institutions in the colonies, are capturing attention. Issues of the debates involving modernity/post modernity are currently being explored in the knowledge field of body and medicine. Modernists focus on the differential availability, and the differences in the quality of the fruits of modern medicine accross boundaries of class, gender, race, etc. They aim at the

democratization of the medical institutions, and a more egalitarian doctor-patient relationship. From the post-modern quarter, emphasis is on the blurring of boundaries between nature-(wo)man-machine, focussing on the contigency and the constructed nature of the knowledge of the body. Roy Porter, in his perceptive account on the "History of the Body", examines "three key areas in which our knowledge of the body is critical to wider interpretations of social change" and points at "seven other branches of the history of the body which deserves close attention" (Porter, 1991).

From the vantage point of colonial studies, changing contours of the medical knowledge of the body in the colonies have received attention. Detailed studies have appeared on the role of the colonial state and academic, legal and other public institutions. The changing economic scenario and the shifting balances of power that affected practices of medicine, have been ably dealt with. There are empirical studies on the encounters of modern medicine with other medical systems (Leslie, 1977; Leslie and Young 1992). David Arnold (Arnold 1993) and Dipesh Chakrabarty (Chakrabarty 1998) have been sensitive to the changes in the epistemic dimension of the body.

'Gender studies' is another key area that has focused its attention on the construction of the knowledge of the body. Earlier feminist scholarship had attended to the problem of the sex-gender dichotomy (Rubin 1975) to separate *biological* sex from the *cultural/social* construction of gender. Later studies have even problematized the presumption of *biological sex* as something natural or "real", in the sense of being beyond the realm of the cultural (Lacqueur 1990, Butler 1993, Clarke and Olesen 1999). In this short essay I cannot speak about this at any length. I could only point out that the focus is the interrelationships between the *body* and the *identity of the self* — on the mechanisms of the social, political and epistemological processes that posit the three dimensional space of the body as the natural focus of identity.

The existence of the body is so 'natural' to our thinking that concreteness and embodiment seem to be synonymous. The body is —that which can be touched, that with which one can touch — the perceived and the perceiver, the object and the subject of knowledge at the same time. To think of the body in such a manner is something new in history, something characteristic of modern forms of knowledge. Modern medicine is the discipline that looks at the body in this way, that looks at *this body.* An archeology of the birth of this medicine may let us recognise some of the new mechanisms of seeing, hearing and knowing that constitute the modern form of knowledge. With the help of Canguilhem, Foucault, Gadamer and Porter, I would try to trace some features of that archeology.

To know is to know something. The subject (of knowledge) knows the object (of knowledge). When the knowledge is science, the object is more real, nearer to truth; or at least it seems to be. Religion, poetry or history try to know some other 'objects', in some other ways. The claim to reality is far less for those objects. Even within the sciences, the objects of knowledge differ in the different disciplines. The *object* of medical knowledge is the *body*. As such, one of the primary steps in the construction of medicine as a discourse is the emergence of the individual body as an object of knowledge. The clinical eye as a new form of knowing and the clinic as a unique institution of knowledge and therapy are implicated intimately in the construction of this new knowledge of the body.

II

Let us quote from Michel Foucault. The two quotes are two descriptions of the body (to be specific, of diseases related to the nervous systems) :

"Pomme saw membranous tissues like pieces of damp parchment ...... peel away with some slight discomfort, and these were passed daily with the urine; the right ureter also peeled away and came out whole in the same way". The same thing occurred with intestines, which" .... peeled off their internal

tunics, which we saw emerge from the rectum. The oesophagus, the arterial trachea, and the tongue also peeled in due course

(Pomme 1769)

.... This is how a doctor observed an anatomical lesion of the brain and its enveloping membranes, the so called "False membranes" .... [in] .... 'chronic meningitis' : Their outer surface, which is next to the arachnoidean layer of the dura matter, adheres to this layer, sometimes very lightly, when they are separated easily, sometimes very firmly and tightly, in which case it can be very difficult to detach them .... The false membranes are often transparent, especially when they are very thin .... The organisation of the false membranes also display a great many differences .... "

(Bayle 1825)

The descriptions are separated by a span of about fifty years. Yet how different their expressions are! What is new in the second description? Answers to this question might give a clue to the new conceptions of the body we are speaking about. The first difference is in the *spatiality* of the metaphors used in the second statement. To describe the body is to describe the space that the body occupies—like the false membranes in the above description. The colour, the volume, the structure, the thickness, whether attached to other structures, and such other specific descriptions. The anatomic structure of the body is the *reality* of the body : that which can be touched, that with which one can touch. On the contrary, the other description, despite its overtly dramatic expressions of the organs peeling away in succession, is non-specific and vague. It is unable to give a clear idea about how the human body is situated in the three dimensional space.

This individual three-dimensional space becomes the *site where disease occurs*. The location of the diseases shifts from the abstract hierarchy of classificatory schemes to the concrete form of the body, from classes to spaces. Fevers were earlier recognised by their types, the class to which they belonged—

continuous, intermittent or remittent, if intermittent the periodicity of the attacks, the associations with other symptoms. In modern medicine, fever is located in the body - resulting from a specific abnormality of a specific part (organ or tissue) of the body. The etiology of a fever becomes inextricably linked with a specific form of abnormality, namely inflammation, affecting a specific organic *space*. The disease is located in a specific three dimensional space with definite configurations of anatomic structure. To describe the disease is to describe the space. To know the disease is to know the changes it brings about in this anatomic space of the body.

The spatiality of the body is intimately related with one other phenomenon — seeing, the clinical gaze. The metaphor of sight, seeing as a way of knowing, gets prime importance in modern knowledges. To know is to make visible what was invisible earlier. Like the fevers that we have already discussed, a disease is known when it is located in the visible space of the body. Only the visible is knowable. Seeing is an act that is passive. The act of seeing does not bring about any change in the object that is seen. The doctor sees, and thus knows, the pure existence of the disease. But the clinical eye is not passive. Its gaze is structured by a theory, medicine. *What the mind does not know the eyes do not see*, is a common proverb among doctors. Let us state the proposition in straightforward terms. An *active* mind is looking at the passive body. The grid of theory captures the reality of the disease — a reality that is not constructed by the theory — that is definitionaly outside the grid of theory. For, the claim is, the theory itself has been built through observations of many real situations. So that it can look at the real abnormalities from the outside, from an Archimedean position.

We now turn our attention to this act of looking. In medicine, the act of seeing is really a composite act. It combines the triad of looking, listening and touching. The resultant composite perception follows the symptoms of the secret disease, goes into the depths of the body, brings them out onto the surface and projects them on the organs of the dissected corpse. It is the gaze that touches, that listens, and only sometimes, sees.

The concept of the body is intimately related to the concept of death. This can be perceived at two different levels. At one level, dissection, the opening up of the corpse, is the inalienable first step to reach the knowledge of anatomy. The three dimensional spatial structure of the living healthy body is known through the knowledge of the body that is dead. In today's medicine, the clinic and anatomy seem to be inseparable. Yet Foucault shows, in minute historical details, that a perceptual leap was required to combine the clinical gaze that perceives the body in a temporal dimension (how the body changes over time) with the anatomic concept of the body that focusses on the spatial dimension. The perceptual leap involved in an explanation of *the temporal dimension of disease* by *the spatial structure of the body* was possible only when the clinical gaze could detect signs of the disease in the space of the corpse — in the tissues, organs, membranes and the other static structures. The crucial move was to discover a cause and effect relation between the disease of the living and the abnormalcy in the visible body of the corpse.At another level of analysis, normalcy cannot be defined without defining abnormalcy and at the other end of abnormalcy, the presence of death. Canguilhem had earlier talked about two dimensions of normalcy. One of these is statistical and quantifiable. The other one is normative. This normative dimension of normalcy is subjective, shifting, contingent—defined by the "others" of the normal. Death is in that sense the ultimate other that defines the normative dimension of health. Yet in the spatial structure of the body, death itself is not unidimensional. At every moment, when the superficial cells of the skin die, new cells are born inside. On the whole, the skin as a tissue is living. In every cell, in every tissue, organ and the body, death is multi dimensional, multi temporal. Pathology is the spatial expression of the differing dimensions of death in the body. Along with clinic and the anatomy, pathology has been one other inseparable part of modern medicine.

Language, rather some modes of expression, description and thinking that involve a new language, is one of the most

important dimensions of this new form of knowledge of the body. To recall Foucault, the emergence of modern medicine as a form of knowledge involves a coming together of the *visible* and the *expressible* —the space that is seen becomes the object of expression through language. To describe a disease is to describe the space where the disease occurs — to know the changes in that space. For, these changes are the symptoms of the disease. In the language of medicine, the metaphors of spatial description gain importance. The symptoms of the disease are captured within the medical gaze — the gaze of medicine, where the passivity of observation and the active network of theory implode. This implosion is made possible by a specific construction of language. The language where the object of vision, the object of knowledge, and the object of expression coincide. The otherwise dumb symptoms of the disease can speak only through the grids of theoretical language. Viewed from another angle, the language of *theory* enables the doctor to read the silent signs of the disease as symptoms, to read those changes of the body which earlier she/he would not recognize as symptoms. As if, it is language that *confers symptom-ness to the spatial changes in the body.* These are symptoms, not the disease. These are the signs, signs that signify something different, that signify *disease.* They are like language, that signifies some *reality* outside. And, language / symptom in a way, constructs meanings /diseases. The doctor sees the body. In the body, the doctor sees something else, the disease. Disease that is the *other* of the body, disease that signifies death.

One important element of this new language of expression is statistics. Medicine locates diseases in the space of an individual body, the body of an individual. The 'individual' as a category of thought has been shown to be a resultant of economic, political and social dimensions of *modern* societies - linked with an individual based market economy, a citizen based modern state and innumerable other dynamics of social life. What is important for us here is that medicine, in its *general universal* knowledge of the *human body,* has to accommodate, account for , variations in the construction of the body in each individual person. The

normal body is to be defined in such a way that it can distinguish itself, draw its boundaries from, the abnormalities, yet be able to account for normal variations at the individual level. To put the question concretely, we quote from a medical textbook : (Park, 1989)

"The daily calorie requirement of a normal adult doing sedentary work is laid down as 2,400 calories.

This clearly is not universally true. There must be individual variations .... Even within the same subject, there may be variation, from time to time. The questions that arise are : what is normal variation? And how to measure the variation?"

Statistics, as a form of logic, is deployed here to make a way out. Statistical measures of dispersion, that can accommodate deviations (from the normal) as variations (of the normal), thus enable modern medicine to define *general* properties in a way flexible enough to account for 'minor' deviations in particular, *individual* cases. This *individuality* becomes an intrinsic property of the generalities of medical knowledge.

Critical theories interrogate categories that seem to be natural. Forms of thinking and experience that remain *spontaneously pre-given* in earlier theories and disciplines are thus rendered problematic. The *body of an individual* is one such category that acts as the pre-given object of knowledge in medicine. This short essay has tried to bring out some of the logical and metaphysical steps in knowledge that were active in the construction of the body. This is not to deny the 'materiality' of the body in presence. Rather this is to bring out the interactions of the material and the ideational that work in the formation of a category. In the process, the specificity of the category is defined in a sharper relief. We gain insights regarding the differentiation of the *individual body* (as understood in modern medicine) from the *single body* (as the instance where general principles like the 'humors' in Greek medicine or the 'doshas' in Ayurveda unite in varying proportions). These insights in their turn bring into focus the specificities of the modern medical

knowledge as distinct from other medical systems. We have spoken about space, vision, language, death, and the logic of statistics which together interweave the body of knowledge that we call the knowledge of the body.

The medical knowledge of the body thus constructed is not homogeneous. It is a complex formed of mutually constitutive knowledges of the body as viewed in anatomy, physiology, biochemistry and other such sub-disciplines. In certain other senses also, the body has been fractured. The metaphors used to describe the body differ, depending on the system which is stressed in the given description. For example, a stress on the neuronal networks (the nervous system) views the wholeness of the body as constituted by contiguous material pathways of communication. This is different from the view where the hormonal effects (the endocrine system) are the central concerns, that conceptualize the body as a system of mobile and interacting fluid elements. The current stress on the immune system, with a focus on the problems of resistance to diseases, of organ transplantations and AIDS, has its view of the body as a system of signifiers of the self and the non-self that often intermix and confuse. This theme of the fracturing of the body is a separate story (Haraway 1993, Martin 1992, Plotz 1996). We would deal with that on some other occasion. In this essay, we have spoken about the emergence of the *body* as the three dimensional space that purportedly holds the disparate (bodily) systems together, may be with some fissures, some holes here and there. A whole, nonetheless.

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SECTION - V

SCIENCE & TECHNOLOGY IN POST-INDEPENDENCE INDIA

V - 1

SCIENCE AND TECHNOLOGY IN INDIA

M. M. CHAKRABARTY

Over the years, particularly in the last three decades, considerable developments have taken place in science and technology scenario in India. The development started from 1916 when Sir Asutosh Mukherjee, Vice-Chancellor of Calcutta University, arranged for the teaching of the fundamental sciences of physics, chemistry, mathematics and botany at the Science College of Calcutta University. He sought from all over India capable people who were at the top of the subject at that point of time and persuaded them to join Calcutta University as teachers. So Prof. C. V. Raman with his brilliant student K. S. Krishnan joined the Physics Department of Calcutta University. Acharya P. C. Ray came from Presidency College to start the Chemistry Department of Calcutta University and Prof. S. P. Agharkar from Pune as Professor of Botany.

It was the British period then, the Indian government was unwilling to spend money for higher education including science and technology in India. However, Asutosh was able to persuade Raja Guruprasad Singh of Khaira to create a professorship in Chemistry. Sir Rashbehari Ghosh and Sir Tarak Nath Palit who were successful lawyers and earned a lot of money were similarly persuaded to donate for the creation of professorships in Applied Chemistry and Applied Physics. It was Acharya P. C. Ray who

persuaded notable scientists of that period to join the newly created departments of Applied Chemistry and Applied Physics. Prof. H. K. Sen became the Ghosh Professor of Applied Chemistry in 1920 by giving up a salary of Rs. 3000/- per month which he was getting from Burma Oil Company at Rangoon to become a professor of Applied Chemistry at Rs. 600/- per month. C. V. Raman was working with a good salary in India Government, Department of Finance, but had already shown aptitude in research and became the Palit Professor of Physics. Research activities were started mainly from the grants from the patriotic Indians. A number of notable findings were made possible; mention can be made of Raman's discovery of Spectroscopy and also Saha's theory on Movement of Planets. Prof. Satyen Bose who was a great mathematician wrote an elegant equation from Einstein's Theory of Relativity, a statistical method which was later known to be Bose-Einstein Statistics. These pioneering scientists put India into the science and technology map of the world. Gradually other institutions developed in the other parts of India such as Indian Institute of Science, Bangalore, Departments of Science and Technology of Bombay University, University of Delhi, University of Madras and also University of Allahabad.

When we want to demarcate the areas where important contributions have been made by Indians, we can think of several areas. Broadly speaking, C. V. Raman, S. N. Bose, K. S. Krishnan and M. N. Saha made pioneering contributions in Physics, Prof. P. C. Mitra made a significant contribution in organic chemistry followed by P. B. Sarkar in the chemistry of rare earths and J. C. Bardhan in important areas in synthetic organic chemistry. The Bardhan-Sengupta Synthesis of Phenanthrene still remains one of the most important contributions in synthetic organic chemistry. As I have said, other centres also contributed important works. Contributions in polymer chemistry and biochemistry came from the Indian Institute of Science, Bangalore. Chemistry of synthetic drugs along with natural products were developed at Calcutta University. Contribution of Prof. P. K. Bose and Prof. Asima

Chatterjee in the chemistry of natural drugs have occupied an important space in the scientific development in India.

Major contributions have been made in the Biochemical Engineering and Biochemistry in IIT Delhi. By and large one can say that work in almost all the fundamental sciences and many areas of applied sciences have been done in many Indian Universities and IITs. Technology of polymer chemistry was a contribution from the Indian Association for the Cultivation of Science which was earlier at Bowbazar area, now shifted to Jadavpur area. The crucial concern remains how can science and technology help us to achieve food, economy and health security.

Concern for society has been expressed by the scientific community in India and Indian Science Congress have played a pivotal role in demystifying science and promoting its awareness among the common people in the country. It is universally recognized that not only the quantitative transformation of a society but its very survival depends on the optimal utilisation of science and technology and becomes meaningful only when the spirit of science is fully assimilated into the social and cultural fabric of our society. Unless the society at large breeds, trains and fosters its scientists and assigns a social priority to the application of science and technology, it will inevitably perish. Practical realisation of the benefits from the application of science and technology in the competitive world can only come with the recognition of the challenges posed by the exponential growth of science with the arrow of time. In 1992 in the Inter-Governmental World Summit held at Rio de Janeiro, it was recognised that humanity stands at a definite moment in the history. We are confronted with a perpetuation of disparities between and within nations, a worsening of poverty, hunger, ill-health, illiteracy and the continuing deterioration of the ecosystems on which we depend for our well being. However, integration of environment and development concerns and greater attention to them, all will lead to the fulfilment of basic needs, improved living standards for all, better protected and managed

eco-systems and a safe, more prosperous future. Therefore, sustainable development becomes an imperative necessity for providing food, economic and health security to all.

Several areas may be considered

1. ***Agricultural Productivity and Environmental Dynamics***

Thanks to Green Revolution, the annual food grain production in India has increased from 55 million tons in 1947 to 180 million tons but the target of reaching 220 million tons to meet the basic needs of over 1 billion people is going to be formidable. Most alarming is the fact that the food grain production seems to have almost reached a stagnant plateau, even though the population in the country continues to steadily increase. While the Green Revolution brought in dramatic increase in food production by involving the large scale use of chemical fertilisers and pesticides, high response of better cultivation and extensive irrigation, the negative repercussions of these farming practises have resulted in rendering vast tracts of once fertile agricultural land into saline or alkaline deserts. Estimates indicate that about 100 million ha. of arable land out of a total of 160 million ha. in India has degraded, half of which is severely degraded and has become unproductive. The agricultural productivity in India is one of the lowest at 1.6 tons/ha. as against world's average of 2.6 tons/ha. in the developed nations. The per capita availability of land is 0.17 ha. as against over 1 ha. in the developed countries. There are no longer fallow periods which were responsible for the restoration of soil fertility. These have got shortened from about 10 years to just about 2 years, due to the large pressure of population.

Rapid deforestation over the years due to the pressure of population and increased industrialisation have reduced our total forest cover to just 20% of the land area. Most of our plant population about 45000 species and the animal population of over 68000 species have been depleted. Already 10% of the flowering plants, 856 species of angiosperms and 146 species of mammals, birds and animals have entered the list of endangered

species. Management of water resources in India has been even more pathetic because of the depletion of forest; total rain fall has come down and there has been very serious depletion of the water resources. Intensive use of chemical fertiliser and pesticides combined with poor management of watersheds has resulted in severe water stress, pesticide contamination with water and agricultural products in addition to unacceptable degradation of soil, resulting in disruption of systems over large areas.

Water and soil erosion have affected almost 40% of our agricultural lands. Year to year climatic fluctuations and changes in rain pattern have further compounded the problem of providing adequate food security, particularly to our vulnerable rural population. Superimposed on the relatively short term inter annual climatic variability, which are generally manifested as a three year cycle, is the effect of irrevocable long term global warming phenomena, resulting from the perturbation of the green house equilibrium due to uncontrolled anthropogenic activities.

The gross neglect of environment has resulted in polluting river waters and surface water bodies, making them fertile breeding ground of many communicable diseases. Destruction of biomass has taken place in big way. This, if not destructed, could have acted as an effective barrier against erosion. In addition to the man -made environmental disaster, frequent occurrence of extreme natural disasters such as cyclone, flood, drought and earthquakes have become a common feature, placing a great burden on the national exchequer and causing serious damage to the people, livestock, agricultural crops and ecology.

About 40 million ha. or one-eighth of the country's geographical area come under the flood-prone region, one-fifth of which or 8 million ha. of area on an average is affected by major floods every year, causing a loss of over 1500 lives and damaging crops and property worth 300 million dollars. In some years such as in 1988, the loss was estimated at 1500 billion dollars due to damage of over 10 million ha. of crop area which affected 60 million people and resulted in the loss of 6000 lives. In addition to the geological disasters, disasters like earthquakes,

landslides and volcanic eruptions are the most violent and extreme geographical events in nature. We have earthquake-prone zones in the Himalayan area and several other places in Kangra Valley and several other localities.

2. *Population Dynamics and Economic Security*

As it happens, despite adoption of population control measures for the last two decades, the lowering of birth rate from 35 per thousand to about 29 per thousand, we are still away from desirable target of replacement fertility rate of 21 per thousand, the present birth rate essentially implies doubling of population of every 40 years. Population stabilisation can only occur when the number of older people dying balance the number of children born, which essentially implies that the demographic stabilisation will occur nearly four decades after the replacement fertility rate is reached. It has been estimated that even under optimistic assumption of reaching the target of 21 per thousand for the crude birth rate by the year 2025, the population in India can only stabilise at 1.8 billion by the year 2065.

A fundamental consequence of the population growth is further reduction of per capita availability of agricultural land to just about O. 1 ha. which is totally inadequate to sustain a large rural population. These result in large-scale migration of rural population to urban areas in search of gainful employment which is the inevitable consequence of the explosive population growth. While development of appropriate agro-based and small-scale industries resulting in value addition to the rural produce can to some extent help in checking the massive exodus to cities, it is just not possible to stop this. However, to some extent development of agro-based industries and value addition to agro products are essential to increase the per capita income to rural areas. Norman Borlaug, the father of the Green Revolution, warned over two decades ago that large-scale starvation of the two hundered million people in the developing nations is as much due to poor productivity as due to their incapacity to afford the price of food. Inevitably, the rural population will go to the urban areas in search of work. This also increases tremendously the

number of urban population. The urban population in India, which was barely 30 million in 1900 has already increased to over 240 million, forming almost 30% of our total population and is expected to cross 400 million by the year 2000. The explosive population growth in urban areas having poor infrastructure and sanitation have turned out large metropolitan cities into mega slums. Over 25% of the urban population in our mega cities still do not have access to safe water supply causing water borne diseases such as cholera, typhoid, tuberculosis, dysentery and gastro-enteritis. Over 20% of the population in many of our major cities are suffering from hypertension, asthma and other respiratory diseases.

Our total per capita energy consumption in the country including conventional and commercial systems is a dismal 0.35 ton coal equivalent, less than one thirtieth of that in countries like U.S.A. It has been calculated for the projected population of 1.8 billion, the energy supply required is 3.5 Terra Watts, even at an average rate of 2 Kw per capita, which represent almost a staggering fifteen fold increase in the total energy production in the coming 50 years. Our capital scarcity inhibits increased energy production. Without such increase it will not be possible to substantially improve our industrial production capacity to ensure economic security to the people in the coming decades. The state of our education, health care, scientific research are at the lowest level in the world. Some of these problems pose great challenges. The prospect for improving the quality of life to the present and future generation of India clearly depends on our ability to initiate sustainable integrated development at both rural and urban segment within a reasonable time frame. Our food security is in danger by the destruction of forests although some improvement in irrigation facilities did occur during the last 50 years. Unless we develop our total irrigation potential to increase total irrigated crop area to about 80 million ha. it will not be possible to increase the total food grain productivity in the country beyond 250 million tons, with the present agricultural practices, which totally falls short of the requirement to produce a minimum of 400 million tons by the year 2050 to provide adequate food security to the projected 1.8 billion population.

There have been indication of utilisation of science and technology in various aspects of Indian life. For example, we have to recognise our inadequacy in such crucial areas such as education, health care, communications and information despite the fact we have the third largest number of practicing scientists in comparison to other developed nations. The number of scientists in India is less than 4.5 per thousand population as against 110 in Japan or over 200 in most of the European nations. The number of scientist involved in research in India is just 0.25 per thousand as against 5 per thousand in all scientifically advanced nations. The outlay of scientific research, which alone can create the necessary technical manpower who can effectively contribute to the wealth of the country, continues at a meagre level of less than 1% of our GDP, which is hardly conducive to the creation of the technological society of the future. In practical terms the total annual expenditure on R&D in India is less than 5 dollars per capita as against over 700 dollars in the developed nations. We have a very high rate of infant mortality which is about 130 per thousand as against 15 per thousand in United States. Despite the advances in medical sciences and health care, pollution, poverty, wide spread illiteracy and environmental degradation in rural areas have resulted in 12 million children in the developing countries dying every year from rampant respiratory and communicative diseases. Inadequacy in every sphere of life has been most visible during the last half a century.

3. *Challenges and Prospects for Improving Quality of Life*

The extraordinary challenges of meeting the basic minimal requirements and providing a minimal acceptable quality of life to present and future generations in India clerly depends on our ability to initiate sustainable integrated development at both rural and urban levels within a reasonable time frame.

Our food security has been endangered through our inability to reclamation of degraded and wasteland. The possibility of addition to arable land in Asia including India is less than 10%. It is also known in India that there are new scientific technologies available in agriculture, fisheries, food production, soil

conservation and other areas that can affect this degradation processes. There has been in recent times the revolution in communication system and information technology. Remarkable development in space technology and its application in India since 1980's have already had a profound and significant impact on the social and cultural life of our people. The communication revolution initiated through INSAT series of satellites, with over 500 km two-way speech circuits covering 140 routes, amounting to over 150,000 route km. have made it possible to establish connectivity even with remote and inaccessible rural areas and off-shore islands. The INSAT had made it possible for a variety of applications such as business, communication, news gathering, rural telegraphy, facsimile transmission and unique innovative, local specific disaster-warning system which has been saving thousands of lives and livestock in the coastal areas prone to cyclone disasters. Over 100 hours of education programme are being broadcast to 4000 schools and colleges every month using INSAT. This has now been augmented by dedicating a special transponder for distance education by the Indira Gandhi National Open University. These examples amply indicate some of the advancements made in the scientific and technological areas.

One happy fact is the resurgence of innovative India. Some of the developments taking place in advanced countries which wanted to leave us behind has been nullified by our own scientific efforts, which has been called denial effect of innovation. For example super-computer was denied to India in early eighties even when it was wanted for weather forecasting. Our country decided to enter this area by using the alternative route of parallel processing. CSIR's National Aerospace Laboratory at Bangalore developed the FLOSOLOVER Mk 1, which was the parallel computing product for computational fluid dynamics. It demonstrated its facilities in 1986. This led Cray Research INC (U.S.) to negotiate with India's Meteorological Department on its safety requirements. The same Cray was reluctant to have a dialogue with India earlier.

In 1987, the major initiatives of creating the Centre for Development for Advanced Computing (C-DAC) in Pune was

launced to develop an Indian Super computer based on massively parallel processing based architecture. United States, unwilling to give a super computer to India earlier, responded by clearing Cray XMP 14 under restriction in 1988. In 1989, the efforts of C-DAC, DRDO, BARC, NAL to develop parallel processing super computers gained grounds and signs of success were visible. Later on C-DAC demonstrated successfully PARAM-8000, a super computer with a peak computing power of 1000 M-Flops. In 1992 C-DAC exported its PARAM supercomputers to Canada, Germany and Russia, whereas others such as NAL's FLOSOLVER MkIII, DRDC's PACE, etc. matched the capabilities of U.S. made mid-range workstations. After watching our capabilities United States authorised the licensed conditional export of high performance computers to several Indian institutions. After watching, United States ultimately (in 1995) released the export of supercomputers to India. In 1998, C-DAC launched PARAM 1000 demonstrating India's capacity to build 100 Giga Flops machine which was scalable further to teraflops, reaching the levels reached by advanced nations. After watching this, United States further relaxed the export controls. During the same year, the CRAY company decided to set up a subsidiary in India. Interestingly the same company had denied the CRAY supercomputers in 1980's. On 11th May 1998, our atomic device Pokhran II was successfully launched. So, we the Indians have been able to meet the challenges by innovative development on our own technological preponderance. We have been able to export our computers PARAM 8000 to Germany, UK and Russia and that said 'Angry India Does It' meaning, India having been angered at the denial of super-computers developed its own.

Another interesting fact in 1988, the Russians had offered a super computer to India. However the Indian team that visited Russia was not too impressed with the level of hardware etc. and finally India did not buy the supercomputer. Now Russia is importing Indian supercomputers since early nineties. In fact they are now negotiating a deal on the PAMAR 1000 supercomputer. So, India has shown successfully that India can do it. There have

been other innovations but the challenges are also remaining.

In 1988, we had produced 200 million metric tons of food grain but that is not enough. We have to feed almost 1.5 billion people with about 350 million tons of food grains by the year 2040. The increased production has to be attained with minimal ecological damage, falling per capita arable land, less irrigation water and less fossil fuel based energy sources. Here in one hand we need to develop cutting-edge advances in modern biotechnology, space technology, information technology and renewable energy technology and on the other hand we need to take cognisance of the best in India's traditional agricultural wisdom and prudence.

We have to produce more from less, only new knowledge can do that. That had been shown by the advancement of modern biotechnology. Now-a-days it is possible by genetically engineered crops. There have been some success stories. Through the great contribution of Dr. Kurien we have become the highest producer of milk displacing United States to the second position. It was due to Operation Flood at Anand. There is also another kind of innovation which is called 'nuts and bolts' innovation. In the market place there is a continuous influx of new products. Now in the present open market dynamics, only superior products, not only in terms of quality but in terms of features, design, content and service, will sell. Therefore, continuous innovation will have to become a part of all our endeavours.

These are some of the things which make us confident that as in the recent past in the coming future also, our scientific community will be able to take up the challenges of other nations and be successful in the long run. We can be confident that India will be the leader of innovation of several countries. I am sure that just as we had launched a freedom movement, which freed us from foreign powers, we can launch an Indian Innovation Movement so that India can assume its rightful place in the comity of nations. and the time to do it is now as the new millennium has arrived.

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V - 2

RECENT PERFORMANCES IN INDIA RELATED TO SCIENCE AND TECHNOLOGY

M. M. CHAKRABARTY

It is extremely fortunate and gratifying that this discussion is taking place after two success stories of Indian scientists and technologists viz. (1) The Pokhran Nuclear Implosion in May 1998 and (2) Launching of ICBM G-2 on 11th to 25th April, 1998. I take this opportunity to congratulate Dr. A.P.J. Abdul Kalam and his associates, Dr. R. Chandrasekhar, Dr. Bandopadhyay and others who have made this possible.

If one has to give an account of recent performances of the Indian universities, laboratories and industries related to science and technology, it becomes a very difficult task.

Before our independence in 1947, after 200 years of British rule, the people's psyche was crippled and even the elite section of the society used to think whatever were foreign was best. Even now after nearly half a century of independence this feeling is visible. The British rulers and earlier other foreign rulers had exploited India and they only had developed three things : railways, from hinterland into the port so that the raw materials of vegetable or mineral origin could be exported; minimum road services to connect important cities from coast; and administration, police and civil services so that civil population was kept under control so that the exploitation would go on.

We had to be satisfied with the doled out finished product after the plunder of our natural products. Even in thoughts most of our leaders (of the society) could not grasp the importance of industrial revolution to the development of the country and as harbinger of possibility.

In 1948 as the Industry Minister of first Congress Government of the then United Provinces (present U.P.) Dr. Kailash Nath Katju was invited to open a match factory somewhere in the state and his eloquent speech stated, "A great step was taken by the opening of the match factory towards large-scale industry." There are innumerable examples of such lack of awareness even among the educated elite and front ranking social leaders.

Inspite of abject and widespread illiteracy there was no encouragement for any education in legal or higher education in science and technology. There was a small core of intellectuals in Bengal which was aware of the development of science and technology in the rest of the world and its relation to the prospertity of the nation. Acharya Prafulla Chandra Ray, Acharya Jagadis Chandra Bose and earlier Dr. Mahendra Lal Sarkar had pursued scientific research under very difficult conditions. Their persistent research for truth even under such severs strains was the real triumph of the human spirit. Their examples influenced many a young man in the dawn of this century encouraged by the intellectual stalwarts like Ashutosh Mukherjee, Meghnad Saha, C. V. Raman, Satyendra Nath Bose, P. C. Mahalanobis and a few others, and they took up research abandoning lucrative offers. These examples had already influenced the younger generation in other parts of the country. Among the pioneers were M. Viswesharya in Mysore state who brought about a revolution by his application of engineering skills. He constructed the dam 'Krishnaraja Sagar' for irrigation and Mysore became a model state. Dr. Santi Swarup Bhatnagar could persuade the then Government to form a Board of Scientific and Industrial Research and could get the support of like-minded intellectuals of the society. Dr. Homi Bhabha, the

architect of our atomic research projects worked at the Indian Institute of Science. Some of these great scientists had defined ideas how developments can be brought about just in the pre-dawn period of independence. Professor Meghnad Saha and Professor P. C. Mahalanobis were instrumental in persuading Pandit Jawaharlal Nehru about using science in our approach to the problems of development. Discussions in the Planning Board of the National Congress brought into acceptance by Subhas Chandra Bose as the then Congress President in the late '30s shaped many of our plans in post independent India. Even then some of the deep seated prejudices influenced and we had to emerge on a mixed economy.

The newly independent India embarked on building new laboratories for its inherited small but vibrant scientific community to work with new science departments of the Govt. of India. Atomic Energy Commission was established. Late depelopment brought space into its purview and an independent Department of Space emerged in early '70s. The then Prime Minister, Pandit Jawaharlal Nehru was so much convinced about th role of science and technology that he kept the portfoliio with himself and also persuaded the Parliament to pass the Science Policy Resolution on March 12, 1958, with a view to depeloping science and technology as an integral part of national endeavour. This was certainly one of his achivements in life and he is regarded as the Architecht of Free India's Science Policy.

It is fortunate for the country that the successive Prime Ministers gave similar importance to the portfolio and kept it under their direct supervision. Sreemati Indira Gandhi also issued similar technology policy statement which reiterated the commitment of the state to the persuance of indigenous technology. Rajiv Gandhi's concern in this connection was laudable and lately in the '90s the document Foster 2020 issued by the Government gives a clear direction in which science and technology are going to play their roles.

What has been done in the last 50 years with such a support can be reviewed now.

Although the beginning few decades following our independence in 1947 were to an extent influenced by Cold War politics or other regional geo-politics, there were achievements which have helped the country to be economically and politically independent and also technologically relevant.

The Green Revolution of the '60s transformed our country from food shortages to food sufficiency. The success story of India should not be under-estimated. However, we have to go much further as our yields are some of the lowest in the world. Although we have eliminated the scarcity due to periodic droughts and famines having built a comfortable buffer stock, there is a lot of possibilities of improvement in all sectors of the agriculture including animal husbandry, poultry farming, horticulture, and zone developments.

One of the success stories is the launching of remote sensing satellite by ISRO. Our own geo-stationary communications and weather forecast satellites are integrating the country in one national village. Already more than 6 million C.Dot telephone exchanges indigenously designed and manufactured are contacting thousands of villages and towns.

Our pharmaceutical industries backed by research in the Central Drug Research Institute, Lucknow, and various university laboratories have made great progress by introducing new indigenous products based on our ancient knowledge of Ayurveda have heen recognised. In this connection I would like to mention the pioneering work at the Chemistry Department of Calcutta University by Prof. Asima Chatterjee and her co-workers in utilising a number of indigenous medicinal plants.

Indigenisation of defence industry was one of the early enterprises undertaken by the Government to be self-reliant. Battle tanks, surface to surface and surface to air missile and nuclear power reactors with the complete knowledge from

designing, fabrication and even treatment of nuclear waste have been possible indigenously.

We have also achieved a lot in developing higher technical education in the country. Along with some universities the Indian Institutes ofTechnology are some of the world's best educational institutions of higher learning in the field of technology. Our engineers have successfully built up big power stations, reservoirs, dams and many other facilities.

But then we have not been able to achieve that much which some of our South-East Asian neighbours like Japan and Korea have done. One of the reasons is that only an atmosphere provided by a more literate people gives the thrust to the development of science. Even after 50 years of independence nearly 50% of our population remains illiterate.

We have been able to eradicate diseases such as small-pox and on way to eradicate polio. Therefore, there is no reason why we should not enter the new millennia 'All Literate'.

Another lacunae in thinking and planning is the lack of giving enough importance to the development of infrastructure. We could have avoided the problems of power cuts, clogged roads and highways, dead telephone, shortage of irrigation and equitable sharing of available water and various other problems. Although western experts may give some guidelines, but then we have to develop our own solutions. For a country of our size with rich history of civilization, appropriate technology would enable us to become strong industrially, economically and militarily. It is necessary to strive to develop a State-of-Art industrial base which will serve us well both in times of peace and war. The strength of a nation emanates from better industrial technology and economic infrastructure. There is no point to produce new technology designed by other nations. We have to develop our own capability and our Space Organisation ISRO has already exhibited how one could achieve this.

I am sure India can rise by her own efforts. The country wants only one thing from us—devotion to duty. After 50 years of

our independence let us try to overcome our deficiencies and do our best to rise above others. A determined nation always wins. Let us be determined so that India can be great and all Indians thrive.

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V - 3

INDUSTRY IN WEST BENGAL — A PROFILE OF FIFTY YEARS

BISWADEB CHATTERJEE

When the erstwhile Bengal was bifurcated to facilitate India's freedom, West Bengal emerged with reduced area and population. Initially West Bengal was allotted 37 per cent of the geographical area of the undivided Bengal with 33 per cent share of its total population. However, a massive influx of refugees from the segregated portion, roughly estimated to be 50 lakhs, not only changed the demography of West Bengal but also put undue pressure on the state's economy, as only 2.5 lakhs of them got rehabilitated elsewhere including at Andaman and Dandakaranya. It caused alarming increase in the density of population from 779 per sqr. mile in the old province of Bengal to 1000 per sqr. mile in the new state of West Bengal. Later inclusions of Cooch-Behar in 1950, Chandannagar in 1954 and some Bengali speaking areas of Bihar, to form a new Purulia district, in 1956 reduced this pressure on West Bengal to some extent.

It should be noted that the partition of Bengal was solely politically motivated and hence did not follow any economic basis. As for example, almost all the jute mills remained in West Bengal although its eastern part comprised the major areas of raw jute production. Similarly, West Bengal inherited 38 textile mills against the 7 of the other part, although cotton

production was mainly possible there. In this sense the partition disrupted the mutual economic dependence of the two parts of the undivided Bengal which grew steadily over time.

The first major problem which cropped up in West Bengal was the food crisis as the state shared only 43 per cent of the rice producting area of the undivided Bengal. But with its endeavour and initiative, the state managed to tide over the crisis by augmenting foodgrains production more than double, to outweigh the population growth during the first twenty five years of separation, with irrigational facility extending to 30 per cent of its net acreage. Besides, production of jute, its main cash crop, also substantially increased which averted the closure of the mills. This was important as the jute mills then employed 2 lakhs of people.

The most important industries of the state at the time of independence were cotton and weaving, jute, tea, engineering goods, iron and steel, chemical, paper, glass, rubber and printing and book binding. Those provided total industrial production of Rs. 2,24,09 lakh to constitute 21 per cent of the net domestic product (NDP) of the state in 1950-51. Besides, the state had rich deposits of coal. In fact, the coal deposit comprised 99 per cent of the total minerals of the state. West Bengal accounted for one-third of the total coal reserves of the country. Other mineral deposits of the state included dolomite, iron ore, manganese, copper etc.

A common belief is that the Centre began to exploit West Bengal as soon as it was partitioned, in similar way as the British did before independence to result in huge drain of wealth from Bengal. The glaring example was the fact that the Centre, on the very first day of independence, reduced the state's share of export duty and of income tax on the plea that it lost the major jute growing area along with sizeable previous portion and population. Then the state was bleeding and what a medicine was put to its wound!

In spite of this, combined with the enormous refugee problem, West Bengal maintained its 1947 position upto 1960 in respect of having maximum per capita income among the states. In respect of industrial production West Bengal was just behind Maharashtra although the state established its supremacy in trade and commerce in 1950-51. In respect of total production, West Bengal was only behind U.P. in 1950-51, but then U.P. was three times as large as West Bengal. Then West Bengal's net output in agriculture and allied activities was 25 per cent higher than that of Maharashtra. At that time West Bengal had the maximum number of registered factories (1493) employing 4.75 lakhs of people. As against this, the composite Madras had 1473 factories employing only 1.80 lakhs of people and the bilingual Maharashtra had 1426 factories employing 5.37 lakhs of people. Then West Bengal was only behind Kerala in respect of literacy rate.

So West Bengal could initiate the planned industrial development in 1951 on a relatively favourable economic scenario, even after being partitioned. But gradually the industrial heritage of the state faded away and its industrial supremacy slipped into the grips of Maharashtra and Gujarat. The process of industrialisation in West Bengal has three marked phases : the first from 1950-51 to 1964-65 which may be called the period of retreat, the second from 1965-66 to 1990-91 which may be called the period of decline, and the third, beginning since 1991-92, may be called the period of expected recovery in conformity with the country's economic reform policy as announced in 1991. This broad classification is only general in the sense that fluctuations in industrial progress had also been noticed within any marked phase.

First Phase

A relatively low growth of NDP in 1960-61 over 1950-51 marks the slow industrial progress in West Bengal. This growth rate was only 30.3 per cent as compared to 58.7 per cent in Maharashtra, 57.1 per cent in Tamil Nadu (then Madras), 47.3 per cent in Bihar and even 38.3 per cent as the average growth

for the country as a whole. Moreover, the state lost its top position in respect of per capita income to Maharashtra in 1960-61. In fact the state experienced a fall by 2 per cent in this respect over its 1950-51 level. This fall continued even in successive years to finally settle the state at the sixth position in 1965-66 lagging behind Punjab, Maharashtra, Tamil Nadu, Gujarat and Assam. Maharashtra also edged past West Bengal in respect of number of industries in 1961. While the figure for Maharashtra was 1724, it was 1373 in West Bengal. In terms of literacy rate, West Bengal also slided down to the fifth position in that year. Although the rate of industrialisation, measured in terms of the share of the manufcturing sector in total state domestic product (SDP), increased in West Bengal from 34 per cent in 1960-61 to the maximum of 36 per cent in 1964-65, it gradually fell afterwards as the state entered into the second phase of industrial decline. Thus, in general, the pre-eminent position of West Bengal in respect of industrial supremacy was snatched by, particularly, Maharashtra, and to some extent, Gujarat within the first fifteen years of Indian planning. It had some important reasons.

First, the partition not only took away our land and population, but also deprived us of our agricultural and industrial base as the eastern part of Bengal provided huge source of raw materials and the market for finished goods as well. Secondly, refugee problem of West Bengal was never seriously dealt. Lakhs of refugees were neither properly settled nor were adequately compensated to rehabilitate. They had mixed up with people this side without any considerable economic activity which could expand the market. Thirdly, on observing massive congestion of industries in and around Calcutta, West Bengal was always treated as an industrially rich state which was not true. In case the industrial belt of Calcutta was detached from West Bengal, the rural industry-starved West Bengal could be prominent. But this aspect of the state was never sympathetically considered. Fourthly, the head offices of almost all major financial institutions and the banks were established in and around Bombay (now Mumbai). Maharashtra and Gujarat took

advantage of this locational benefit and made industrial advancement at the cost of other states. Fifthly, even a statesman of Dr. B. C. Roy's stature, who almost alone bore the responsibility of reorganising the partitioned economy of the state, over-burdened by the refugee problem, and laboured hard to set up a cluster of industries in and around Durgapur on a decentralisation move, could not resist the much controversial Central policy of 1956 which equalised railway freight of coal and iron and steel from the sources throughout the country. This, obviously, snatched the natural advantage of West Bengal and other eastern states to use those as industrial inputs. Sixthly, in the same year also came the policy of uniform cement price throughout the country. Since limestone and dolomite, the two major inputs of cement were cheaper in South India, the cement factories had concentrated there. In fact, South India had 85 per cent share of total cement production of the country in 1971. Seventhly, some tax measures were adopted to shrink the revenue-raising capacity of the states like West Bengal. On the plea of maintaining uniformity in respect of taxing inter-state sales and removing inter-state disparities in taxing certain important goods, the Centre enacted the Central Sales Tax Act, 1956 and the Additional Excise Duties (Goods of Special Importance) Act, 1957. The former act was to cover mostly industrial inputs and its provision of very low and concessional rate made West Bengal one of the worst sufferers, as the state could not properly tax its important products like iron and steel, coal, jute and tea when sold to dealers of other states. Besides, the state was constitutionally debarred from taxing exports of its jute and tea, but it was never compensated as the share of customs duty was not put in the divisible pool. Apart from revenue loss, this also neutralised West Bengal's natural advantage, of having proximity to these items, to hinder its industrial prospect. Revenue deprivation of West Bengal was, however , more acute in respect of the 1957 act which levied additional excise duties on cotton textiles, silk fabrics, sugar and tobacco. Excepting sugar, the other three were important products of the state. It was a tax rental agreement as, out of the

total proceeds, the states were to be paid a fixed portion as determined by a formula agreed on then and a flexible portion was to be revised by the successive finance commissions. It had a paultry revenue impact as the states' demand to switch over the tax from being specific to advalorem was not complied with. It deprived the states, of the substantial effect of inflationary gains on revenue. These two taxes could be termed as illogical encroachment into the legitimate tax jurisdiction of the states and thus had been important issues to strain the centre-state financial relations. Eighthly, owners of many of the undivided Bengal's renowned factories like the Dunlop, Bata, Phillips, Hindmotor, Usha etc. did not prefer West Bengal to expand their business and opened new units elsewhere outside the state. Lastly, West Bengal had no powerful lobby at the Centre to see and protect its industrial interests nor any important minister after Mr. S. C. Bose who departed the central cabinet in 1946, and Mr. S. P. Mukherjee who resigned from the same in 1950. Thus West Bengal was not only neglected but was also denied its due share of industrial licenses.

All of these had contributed to the state's retreat in respect of industrial progress. The flow of industrial prosperity of the fifties had been receding to pave way for the ultimate decline in the next phase.

Second Phase

Industrial production in West Bengal in this phase had passed through small spells of deceleration and recovery, although the overall decline was no less prominent. The state experienced near stagnation in industrial production in subsequent years since 1965-66. It is seen that the index of industrial production in the state, with 1963 as the base, was 112.8 in 1965 but fell gradually to 64.1 in 1973. The stagnation reappeared in the later half of the seventies and the index with 1970 as the base decreased from 121.9 in 1977 to 117.4 in 1980. The index again fell in 1984 over its level in 1981. The situation, however, began to improve, although slowly, since 1985. As a result of all these, industrial production grew at a very low rate in West Bengal as

the index finally rose to only 136.0 in 1988. Industrial deceleration in the state was also reflected in the index with 1980-81 as the base. While this index increased to 204.6 in 1988-89, the corresponding increase at the all India level was 301.8. Similarly, with 1960-61 as the base, while the industrial index rose by 13 times in West Bengal, the corresponding increase for the country was by 40 times. As a result, both in respect of per capita gross output and per capita value added, Maharashtra ranked first among the states in 1988-89. These were Rs. 5,370 and Rs. 1,130 in Maharashtra against the low figures of Rs. 1,940 and Rs. 647 in West Bengal in that year. Besides Gujarat, Tamil Nadu, Karnataka and Punjab also showed much better performance than West Bangal in such regards. The figures for West Bengal were even lower than the corresponding figures for the country as a whole. In comparison to West Bangal, the index of industrial production in Maharashtra had registered a steady rise throughout the entire period of our second phase.

In West Bengal, the sluggish performance in the industrial field was also evident from the declining share of the manufacturing sector in total income of the state. It was 36 per cent in 1965-66 but reduced to only 25 per cent in 1991-92. It confirms that the rate of industrialisation in the state had declined over time. As an important reason, the registered factories grew in small numbers in West Bangal from 5,837 in 1977 to only 6,421 in 1980 and further to only 8,573 in 1988. Upto 1980, these factories had fixed capital of Rs. 1.39 lakh. With employment of 9.34 lakhs of people, commodities produced by them had valued Rs. 4.08 lakh. One important feature of the industrial employment here was that non-Bengali workers dominated the Bengali workers in number, the ratio being 58:42. As against these, Maharashtra had 13,075 registered factories upto 1980 which employed 11.25 lakhs of people and produced commodities worth Rs. 9.33 lakh. It shows that factories in Maharashtra were able to produce 110 per cent more than West Bengal with additional employment of only 20 per cent. Gujarat was slightly behind to produce goods worth Rs. 4.22 lakh in

9,655 factories which employed 6.36 lakhs of people. Against Maharashtra's usage of 16 per cent of the all-India use of electrical energy, West Bengal could use only 8 per cent.

Industrial production in West Bengal had suffered due to low productivity, both of labour and capital. The giant steel plant at Durgapur could not reach its rated capacity even within the 20 years of its inception in 1960. Production of almost all important items like jute goods, cotton goods, iron and steel (barring the semi-finished steel), tea, etc. had a slump in 1989 over 1970. Only wagon manufacturing had a marginal rise. Emergence of synthetic fibre as a substitute of jute in preparing carrying bags had caused havoc to the decline of jute industry in the state. The non-Bengali owners' reluctance to introduce product diversion in time had also contributed to it. Unemployment problem in the state was intensified as the mumber of industrial units closed had exceeded the number of units re-opened in each year since 1970. Hence while the exfactory value in West Bengal increased by only seven times in 1985-86 over its 1960-61 level, such increase was by 40 times for the country as a whole. As a corollary, West Bengal's contribution to industrial production of the country gradually fell from 23 per cent in 1960-61 to 14.4 per cent in 1970-71 and finally to only 8 per cent in 1985-86. All of these amply demonstrate the declining phase in respect of industrial evolution in the state. It had many reasons.

First, the socio-political situation in the state was against the industrial growth. The rise of the communists at the helm of the state's political power, through the 1967 assembly election, gave rise to violent trade unionism in the state. Cases like gherao and physical assault of the managers/owners of the factories were rampant. This created fear and anguish among the entrepreneurs. Strikes and lock-outs in factories became almost common in those days. The labour unrest gradually increased as the state plunged into political turmoil in absence of any stable government even after the 1969 and the 1971 elections.The number of labour disputes was 275 in 1961 which

suddenly increased to 419 in 1969. These involved 7.97 lakhs of labours and the man-days lost were of 98.81 lakhs. The number of strikes was 272 in 1970 which was 297 in 1969. The then ministers and the trade union leaders also complained about the owners' evil motive to lock-out their factories under any pretext. In fact, the lock-outs caused the state to suffer from huge loss of industrial production. In respect of such loss for the country as a whole, West Bengal alone accounted for 61.8 per cent in 1967 and 63.4 per cent in 1968. Although many often cited gheraos to be the sole cause of factory lock-outs, the ongoing economic depression was also largely responsible for it. The trade unions also flourished in number, from 1,951 in 1947 to 10,496 in 1972. Low industrial wage in West Bengal, particularly to the skilled workers, might be a strong reason for it. Although the intensity of strikes and lock-outs fell down in the state in later period, the state could never come out of it. Labour indiscipline, strikes and lock-outs continued to retard industrial growth of West Bengal as, even in 1986, man-days lost amounted to 14,835 thousand involving 146 thousand of labours. This was the highest in the country. Secondly, the Naxalite movement had also rocked the West Bengal's economy. Indiscriminate killing by rival parties almost broke down the law and order of the state. Fear-psychosis prevailed in people's mind and particularly in the minds of the entrepreneurs which almost stagnated the industrial progress during the period from 1967 to 1975. Thirdly, the liberation struggle in the erstwhile East Pakistan (presently Bangladesh) and the consequent repressions by the Pakistani military led further influx of lakhs of refugees in West Bengal in 1971. It imposed severe burden on the state and its economic activities were disrupted which precipitated the on-going crisis. But this aspect of the state's economy was never sympathetically dealt nor the state was compensated appropriately. Fourthly, the financial institutions including the banks maintained discriminatory policy against West Bengal in disbursing industrial credit. During the 10 year period from 1969-70 to 1977-78, while West Bengal received Rs. 219.25 crore from them as such credit, Maharashtra and

Gujarat respectively received Rs. 574.50 crore and Rs. 322.38 crore. Upto 1984, the scheduled commercial banks sanctioned Rs. 12,224 crore to Maharashtra against only Rs. 4,332 crore to West Bengal, even though West Bengal had higher bank-man ratio. Fifthly, the centre had discriminated against the state in providing industrial raw materials like steel, copper, zinc, lead, nickel, aluminium etc. The centre also did not pay heed to the state's demand to make freight equalisation in respect of cotton and chemicals, as it did in case of coal and iron and steel in 1956, which provided additional advantage to the western states to flourish in such industries at the cost of the states like West Bengal which had short supply of these. Sixthly, the centre's apathy towards West Bengal's economic progress was also evident from the discriminatory distribution of industrial licenses. As against of 163 letter of intents and 243 industrial licenses which Maharashtra received from the centre in 1975-76, West Bengal got only 61 and 71 respectively. In 1986, West Bengal was granted 21 industrial licenses when it was 96 for Maharashtra. Seventhly, the Bengalees were reluctant to undertake risky ventures like setting up of industries. As a result, entrepreneurship did not grow from within which made the state to depend on outside investors. But they had more interest to see Calcutta as a business centre, because of its enormous population rise and geographical location, than to build it up as an industrial centre. Thus lack of internal initiative turned Calcutta to be an important trading centre, not only of West Bengal but also of the entire eastern region, in lieu of being a production centre. Eighthly, lackadaisical and passive attitude of the state government was also largely responsible for it. In fact, it often seemed that it was more interested in voicing discrimination than actual work. After Dr. B. C. Roy, who initiated the process of reconstructing the state economy by building up educational and infrastructural base on taking advices from noted economists like Vakil, Bhabatosh Dutta etc. and scientists like Meghnad Saha, Triguna Sen, Debesh Mukherjee, Kapil Chatterjee etc., no such leadership emerged. Even the West Bengal MPs, unlike their counterparts from other

states, especially of the south, were never unanimous in presenting the state's case to the centre. Ninthly, the state public sector enterprises had run on inefficiencies and thereby incurred losses. By 1985-86, only 12 of 45 of such state units gained profit to the tune of Rs. 7.05 crore, while 20 incurred losses to the amount of Rs. 83.85 crore. Of the losing concerns, the notable were the CSTC, CTC, DPL, DSTC, WEBEL, DCL, Shalimar Works, etc. The state also failed to induce initiative to set up small scale industrial units. As compared to the Small Industries Corporation of Maharashtra (SICOM), which did commendable job there to expand such units, the concerned authorities in West Bengal had performed lowly. As a result, the state had a relatively low growth of small scale industrial units. As compared to the increase by 30 times in West Bengal, Maharashtra had achieved 45 times increase in this regard. Although the state had announced its plan to set up important growth centres in places like Asansol, Durgapur, Farakka, Kalyani, Haldia, Kharagpur, Santaldihi, Siliguri etc., no significant progress was visible upto 1987. So was the case with the Falta free trade zone. Tenthly, infrastructural inadequacy had caused set back to its industrialisation. Electrification and road transport are considered to be important determinants of a state's industrial potential, but in respect of both of these, West Bengal's performance remained unsatisfactory. The process of electrification in West Bengal was jeopardised by problems like low utilisation of the installed capacity of generation, increasing transmission loss and the theft of power resulting in lags in town and rural electrification. The state had a 36 per cent utilisation ratio against the national average of 54 per cent during the sixth plan period. Although the situation improved later on and the state achieved a plant load factor of 45.4 per cent in 1989-90, it declined futher to 42.2 per cent in 1992-93 when the national average was 53.2 per cent. Stealing of power could be easily inferred from the mismatch between energy available and energy disbursed in a year. This gap in West Bengal increased enormously from 349.4 million units (Kilowatt/hour) in 1960-61 to 5883.18 million units in 1990-91. As a result, the

ratio of the electrical energy sold to different users to total energy available in the state decreased rapidly from 88.6 per cent to only 59.9 per cent over the said points of time. It pointed out the growing problem of theft as well as loss of power during transmission. Against the national average of 18 per cent, such loss in the state comprised 22 per cent of the total energy transmitted in the later year. Such lapses naturally impeded the electrification programme in West Bengal. Despite a huge rise in expenditure on rural electrification, the state could electrify only 73.9 per cent of its 38,074 villages while Maharashtra had achieved cent per cent success in this programme within 1992. Punjab achieved the same feat much earlier. In this respect, the national average was 84.2 per cent. Besides this, while Maharashtra and Punjab could complete electrification of towns by 1980-81, West Bengal did that in 1986-87. As a result, per capita annual consumption of electricity was low in West Bengal as compared to the better-off states including Orissa, and remained even below the national average since the mid-seventies. Such consumption increased in West Bengal, only meagrely, from 79 KWH in 1960-61 to 136.72 KWH in 1988-89. While the respective figures for Maharashtra, Orissa and Punjab were 377.04 KWH, 200.63 KWH and 659.66 KWH, the national average was 216.48 KWH in the later year.

In West Bengal, another major impediment had been the poor road transport facility. The state not only had the minimum length of roads, its success in surfacing the roads was also not satisfactory as compared to other major states. In an area of 100 sq. km., West Bengal had a road length of only 69 km. when it was 70 km. in Maharashtra, 107 km. in Punjab and 112 km. in Orissa in 1988-89. In West Bengal, the same increased to 77 km. in 1995-96. Moreover, when West Bengal could develop 65 per cent of its total road length as highways, it was 85 per cent in Gujarat, 82 per cent in Maharashtra, 76 per cent in Bihar and 68 per cent in Punjab in 1990-91. While surfaced road in West Bengal covered 44.3 per cent of the total length of all types of highways in the state, the proportion was 66.0 per cent in Maharashtra in 1987-88. Punjab completed the task of

surfacing all its highways earlier. The national average in this respect was 50.9 per cent. Besides, against the national average of 71.9 per cent, surfaced road constituted only 69.2 per cent of the total length of urban roads in West Bengal in the said year. By this time, Maharashtra and Punjab were able to complete surfacing of 82.5 per cent and 85.0 per cent of their respective length of urban roads. Such a gloomy picture of road construction and development had its likely effect on the growth of motor vehicles in the state. As a result, the proportion of motor vehicles registered in the state in the same for the country as a whole fell drastically from 15.9 per cent in 1960-61 to only 4.7 per cent in 1988-89. As against this, Maharashtra had 13.7 per cent and Punjab had 6.5 per cent share of the country's total motor vehicles in the later year. Moreover, while the number of such vehicles per lakh of population was only 1,052 in West Bengal, the corresponding figure was 5,472 in Punjab and 3,058 in Maharashtra in 1989-90. For the entire country, it was 2,085.

Finally, demand impetus for boosting industrial growth was also absent in West Bengal because of relatively high poverty ratio in the state. Upto 1975-76, West Bengal had the combined poverty ratio larger than the national average. According to the 1987-88 estimate, West Bengal, as compared to the country's average, had lower rural poverty but higher urban poverty. These were 30.3 per cent and 20.7 per cent respectively. The latest estimate of 1993, however, showed an increasing trend in its rural poverty. In fact, rural development in West Bengal was slowed down by inadequate expansion of irrigation and meagre supply of electricity to agriculture. Against the Punjab's figure of 91.7 per cent, West Bengal could provide irrigation to only 22.8 per cent of its gross cropped area upto 1987-88. In this respect, the national average was 32.5 per cent. In respect of energy supplied to agriculture, performance of West Bengal lagged far behind those of Punjab and Maharashtra over time.

In terms of population living in urban areas, the annual rate of urbanisation in West Bengal was estimated to be 0.3 per cent

for the 30-year period from 1960-61 to 1991-92. But it was as high as of 2.5 per cent in Orissa, 1.3 per cent in Maharashtra and 0.8 per cent in Punjab when the national average was 1.2 per cent. Low urbanisation meant low level of commercial activity in West Bengal over time, as is indicated by the fact that the state had the minimum use of telecommunication facility. Upto 1994-95, there was a single telephone per 667 people in West Bengal as compared to that per 50 people in Gujarat, 60 people in Punjab, 80 people in Karnataka, 98 people in Tamil Nadu, 117 people in Andhra Pradesh and 119 people in Maharashtra to mention a few advanced states. Low urbanisation had not only slackened its revenue collection but also hampered its economic growth as the state recorded only 11.1 per cent increase in its SDP over the said 30 years upto 1991-92, when the corresponding estimates were 13.5 per cent in Punjab, 12.6 per cent in Maharashtra and 12.1 per cent for the country as a whole.

THIRD PHASE

Finally we reach the period of hope and aspiration to recover the economy from the above said problems. Although we have mentioned this phase as beginning since 1991, a new thinking for industrial progress has been evident in the CPI(M) top brass since winning the 1987 assembly election, considering rightly that economic prosperity of the state is hidden in its industrial recovery. Pragmatism and rational thoughts of the chief minister have helped the state to look forward with positive vision of industrialisation. As the left front government tried hard to achieve rural prosperity through implementing land reform and ensuring political decentralisation through the three-tier panchayati system during its first two terms, it began the third term with efforts to consolidate the progress attained thereby, which still continue. But infrastructural bottleneck stands in the way that must be removed.

The government has undertaken several important measures, since the mid-80s, to improve the sagging industrial condition in the state. These included setting up of many powerful bodies

like the WBIDC with its shilpa bandhu or the single window scheme, the WBIDFC, the WBIIDC, the Cabinet committee on industry under the chairmanship of the chief minister, two high-powered committees under the supervision of the chief secretary, one national task force headed by the chief minister with representative of central and state governments and industry, a state-level task force, a board of trade under the chairmanship of the commerce and industries minister with an export promotion cell and district level committees under the district magistrates. These are supposed to help investors, particularly the NRIs and the foreign investors, by providing land, developing infrastructure and facilitating exports. Development of specific industries was emphasised through creating separate bodies like the WBAIC (agro-industries), WBATC (agro-textile), WBTDC (handloom and powerloom) etc. Priortity was given to the promotion of small scale industries by establishing the WBSIC to initiate a special entrepreneurial development programme. Besides, industrialists all over the world were invited to attend seminars and conferences elsewhere in the state including the one as "Destination West Bengal" at Raichak, and the latest one as "Horizon 2000" at Durgapur, to apprise them of the state's industrial prospects. Organisation and participation in industry and trade fairs throughout the country has been common. The chief minister, the WBIDC chairman, the industry minister and bureaucrats have made repeated trips abroad for the same purpose. All of these have strengthened the hope of recovery. The abolition of the much controversial freight equalisation policy on coal and steel in the early 90's has reestablished the state's comparative advantage in respect of industrial investment on those.

The WBIDC has been pursuing a very important promotional role in this regard. Apart from signing of MOUs, it has also undertaken systematic techno-economic study of the state's infrastructure. The Partha Ghosh and Associates was first entrusted with the work which segregated the state into four socio-economic zones to prescribe suitable industries for them. The Mckinsey and Company also highlighted the favourable

points of the state which can brighten its industrial scenario. A 26 member Task Force comprising of several experts have suggested necessary improvements in this field. West Bengal has a large market which is not only third in size, after Maharashtra and U.P., but also constitutes one-tenth of the total Indian market. It also possesses 25 per cent of industrial assets with 15 per cent of factories of the country. The state also has a low competitive intensity. All of these should be turned into an industrial revival through the increasing pro-investor stance. A growing agriculture is also expected to provide the industrial base of the state. Besides, 4.90 lakhs of the SSI units are operational in the state not only to serve consumers' versatile choice but also to provide important raw materials to big industries.

Haldia is expected to show the path. Keeping behind 23 years of the centre's non-cooperation and the state's lethargy, the dream of the gaint petrochemical plant has come into reality as the naptha cracker plant, the mother project, has just been commissioned. Several downstream projects are in the offing to participate in the state's industrial recovery. 1350 of such projects are expected to provide 2 lakhs employment within the next five years. Disintegrating infrastructure there, however, needs to be improved. Since 1991, several MOUs, involving about Rs. 48,000 crore have been signed of which 36 per cent have already responded and set up their projects. Many of these are joint ventures with the state. More than half of these are relating to NRI/FDI schemes. A special body, the WBP, has been created to supervise the project implementations. The state's new incentive scheme of 1993 and the industrial policy of 1994 have regenerated confidence into the entrepreneurs' minds. Based on the state's potential, the government has identified a number of sectors which can accelerate industrial growth. These include, apart from petrochemical and downstream projects, electronics and information technology, leather and leather products, food processing and agro-based industries, gems and jewellery and tourism and related activities. The FICCI has also listed some more thrust areas which deserve

special consideration. These include iron and steel, metallurgical and engineering, textiles, medicinal plants, rubber, palm oil and tea, manufacture of basic drugs, chemicals and pharmaceuticals, etc. Optimal utilisation of minerals and development of mine-based industries have also been stressed by it.

As the central government has adopted economic reform policy with emphasis on liberalisation and privatisation measures, a new opportunity arrives to the state to pursue a concerted effort to foster industrial rejuvenation. This has yielded result as the state's industrial production has steadily increased from a 4.3 per cent growth in 1993-94 to a 9.4 per cent growth in 1997-98. There is enough scope to further improve it as the state's labour productivity is still low even as compared to the neighbouring states and hence must be increased. The global investors are now turning to the state for even investing in its infrastructure projects including roads and highways. The Durgapur Expressway and the Panagarh-Morgram Road to near the distance of North Bengal bear the examples. As the NTPC has begun to generate and supply electricity to the state since the late eighties,power shortage position in the state has significantly improved. In fact, such a favourable atmosphere and optimism on all fronts is likely to bring in industrial resurgence in the state in near future.

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V - 4

A CRITICAL STUDY ON THE STATUS OF CHEMICAL INDUSTRIES IN WEST BENGAL (WITH SPECIAL EMPHASIS ON P.S.U'S)

KALYAN KUMAR DASGUPTA

1.01 Having spent about twelve years in top management position of two public enterprises -one of them being basic chemical industry and the other a core sector industry, a part of which is coal based chemical industry, I would mainly confine my study on these two industries based on my personal experience. I would also broadly mention about the potentialities of the resource-based industries of West Bengal.

2.01 PROSPECT OF CHEMICAL INDUSTRIES OF WEST BENGAL

There have been endless discussion about flight of industry from West Bengal in post-independence era. Politics at the national and state level have been apportioned a fair share of the blame. While a debate on the subject would be endless and no unanimous decison is likely to evolve, it will be better to have a look into objective explanations based on scientific and commercial considerations. The points to be debated are :

Distance from major resources

Distance from major end users

Lack of focus on R & D and Technology renewal

Work culture and productivity

Infrastructural problem

While all these ring a true bell, albeit of variable intensity, there seems to be a better reason embracing and surpassing it all.

2.02 Gujarat has some very important resources but, the flourishing of its chemical industry, not necessarily in the petro-chemical field, is a relatively recent phenomenon. It prospered inspite of terrible water shortage, lack of trained man power, high cost of power and an ever-increasing Govt. insistence on pollution control.

2.03 There is, therefore, a prima facie need for examining West Bengal's industrial health in the light of attitudinal and other intangible problems. What is more important is perhaps a joint approach between the state, polity and the industry in chalking out relevant policies to bring it about.

2.04 *Studies* :- Not too long ago Arthur D. Little and ICICI had done a probing study of the development potentials of those industrial clusters in West Bengal which contribute meaningfully, or hold promises to do so, to the net State Domestic product. The report was presented to the Govt. of West Bengal in January, 1995. It had identified industrial clusters with growth potential. Thanks to the long cherished dream of Haldia showing definite signs of fruition at that time, petro-chemicals found a prominent place in D. Little's short list. No other stream of the chemical industry was singled out, not even as a major adjunct of a cluster.

2.05 Another study was recently made by Partha Ghosh & Associates which had reportedly gone into district-wise opportunities on the basis of resource proximity. There had been several and other independent studies carried out over the years.

3.00 Resource based opportunity

3.01 It may be relevant to touch upon a few of the resource based opportunities which have not yet been exploited.

3.02 ***Coal based opportunities :*** Coke oven hydrocarbons (toluene, benzene, xylene) had ruled the roost for many years before the petrochemical sector took over. The impurity disadvantage can be bypassed by value added direct chemical conversion. Potential exists for a phenol based downstream cluster and benzoic acid/benzaldehyde-based cluster.

In West Bengal there are coke-ovens in the steel plants of Durgapur and IISCO. Durgapur projects Ltd. of state sector also have under-utilised capacity of coke-oven. Unfortunately productions of coke-oven hydrocarbon is much below the installed capacity and not sufficient attention has been given in this sector as the focus of steel industry is elsewhere. As a result, new industries utilising coke-oven hydrocarbons are not coming up as new enterprises must be sure about reliability of supply of raw materials.

3.03 ***Mineral based opportunities :*** Purulia is gifted with a generous deposit of rock phosphate which is blighted by 8-15% ferrous impurities. Much of the iron is in oxide form and magnetic separation technologies are known to be available within the country. After removal of iron, the rock phosphate can be a starting point for fertiliser and / or phosphoric acid manufacture.

Technologies are known to exist for manufacturing refractory materials from dolomite. In that sense, dolomite deposits in and around West Bengal present value addition opportunities. In the same ilk, possibilities are there for limestone and magnesite deposits. Although the opportunities are there, hardly any positive action has so far been taken. For limestone and magnesite deposit survey so far done is inadequate to attract any industrial undertaking. Separation of ferrous impurities of rock phosphate has been developed only in marginal scale. It may be worthwhile to initiate a collaboration with organisation like National physicial Laboritories for removal of ferrous oxide.

3.04 ***Herbal Resource opportunities :*** Geranium is being interplanted in tea garden and geraniol is extracted by steam distillation. The product is exported to overseas manufacturers

of aroma chemicals. The value addition prospects are enormous if investments are made for local aroma chemical production as the final products command very high values. Fatty alcohols of botanical origin constitute yet another prospect in the cosmetic field. These chemical industries are yet to develop in India as appropriate technologies could not so far be developed indigenously. Several other interesting opportunities have been charted by the Regional Research Institute, Jorhat.

Some herbal resources of North Bengal are being utilised by West Bengal Pharmaceutical & Phytochemical Development Corporation.

3.05 ***Downstream opportunities in Haldia*** : The fate of 65000 Mt of benzene, a byproduct of the proposed HPL project is undecided as yet. If some entrepreneurs venture to convert this to phenol, it can trigger off a plethora of possibilities in pharmaceuticals & phytochemicals. Mitsubishi Chemicals have started project work on a one million tonne pterephthalic Acid (PTA) plant with imported paraxylene and acetic acid. Bulk of the produce will be shipped back by the company to the overseas, polyester yarn & staple fibre plants. The remainder will be available in the Indian market in competition with Reliance. Opportunity exists for a polyester plant in Haldia if ethylene glycol is available . Though already earmarked, HPL might be persuaded to reconsider diverting a part of their ethylene production towards such a venture.

3.06 ***Transformation of potential to reality*** : The thumbnail sketches outlined above lie in the realm of distinct possibilities. Whether such projects are viable or not, has to be examined in greater details. It is necessary for State Govt. to take visionary initiative to make it possible to transform some of the possibilities to realities. Investment has to come from business world once the possibilities are examined in greater detail.

3.07 Though there has been a flight of chemical industry from West Bengal, opportunities do exist for new ventures firmly entrenched in local resources.

A great deal of initiative and missionary zeal is needed to convert them into reality. As a first step meaningful dialogue is required among Govt. Industry and Body polity. Technology base is required to be strengthened keeping in view the petrochemical complex at Haldia and availability of imported technology in this area.

Infrastructural Development : Infrastructural development in chemical sector needs huge investment in the form of R&D for new technology based on available resources and overall demand. It is true that National Laboratories are there and there are technology development organisations and under normal circumstances they could meet the requirement of infrastructural development. But an organisational set up with Govt. has its limitations. A lot of interlinking of these organisations are required to evolve the correct technology. One Technology Development organisation or one National Laboratory may not be able to find out solution of all the problems required to build up a new technology. A lot of interaction will be required to get help of one organisation to solve the problem of another. Whenever such occasion arises, we are often bogged down in non-issues like, who would get credit of such development. Often the main objective is lost sight of and these non-issues come to the surface. As a result we are still dependent on imported technology and sometimes buy outdated technology as we did in case of phenol plant of Durgapur Chemicals Ltd.

4. Role of Public Sector Enterprise for Development of Chemical Industry.

4.01 When India achieved independence the nation chose a socialistic goal with mixed economy, where public enterprises had a definite role to play. But there was no serious effort to give a sense of direction to the public enterprises and the measures of accountability were not clear. As a result public enterprises drifted far away from their objective. Sense of accountability did not crop up and corruption became rampant in the sector. Since 1991 our policy leaders have taken a 'U' turn in their strategy. While

upto 1990 public enterprises were regarded as panacea of all problems, since 1991 we have started thinking that public enterprises are responsible for all evils. Privatisation and disinvestment of public undertaking are the order of the day under pressure from W.T.O. While I do not want to raise any controversy on the subject , I would only submit that a serious effort was necessary to probe the problem of public sector enterprise before issuing a death warrant.

4.02 ***Objectives of public sector undertaking (PSU):*** If we want the public enterprises to march ahead, they must have sense of direction in the form of well-defined objectives for different sectors. In view of wide-spread activities of PSU's and varieties of companies and economic activities, the preparation of a specific objective is not a simple task. It needs considerable care and comprehension. Central Govt. Undertakings Bureau of Public Enterprises (BPE) was given the task in 1963, the task was never fully done. If we look into the financial result of public enterprises we get a dismal picture and this explains the present decision to privatise the public enterprises . It was argued earlier that profit was not the only objective of a public undertaking. In this context identification of objective of a public undertaking becomes all the more important. This may include broad economic changes that the govt. then wished to bring about through the agencies of P. S. U. While the social objectives of the business are important, this can hardly justify the unviable current operation of most undertakings. Some public undertakings were shy from the concept of commercial viability as understood in the private sector but an eye should have been kept on overall viability—social, technical and economic.

Some of the basis maladies of public enterprises in chemical sector are :-

* Very low capacity utilisation.

* Low output / input ratio

* Management failure

* Non-availability of required quantity and quality of raw materials

* Excessive man power

* Absence of work culture

This is in general common to all public enterprises. I am not analysing these causes for brevity.

5.00 Durgapur Chemicals Ltd and it's problems

5.01 ***Background*** :- My emphasis here would be the efforts to revive D.C.L. between 1990 and 1997 when I was one of the persons involved in the effort. Before entering into the subject it may be worthwhile to speak a few words about the background. It was dream child of Dr. B. C. Roy. It was incorported on 31.7.1961 as a public Ltd Co. under Indian companiesAct, 1956 for the establishment of a chemical industry in the vicinity of Durgapur cokeoven plant and power plant of Durgapur projects Ltd. The Chemical Co. was launched utilizing all by products of Durgapur Coke ovens for the manufacture of basic and organic chemicals.

5.02 Durgapur Chemicals utilised power and water produced by Durgapur projects Ltd. but failed to utilise the by product of coke ovens as the by product plant of D. P.L worked with very low utilisation of capacity and failed to produce scarce by product chemicals. For last 7/8 years the by-product plant of D. P. L is totally idle. During initial years cokeoven gas of D. P.L. were utilised in D. C. L but ulitimately D. C. L considered it more economic to switch over to cylinder gas.

5.03 The project report of D. C. L was prepared by Krebs and CIE Paris in April 1962. The experts while analysing the project came to a definite conclusion that it was not a project report worth the name. Phenol plant of D. C. L was based on an out-dated technology and never worked beyond 15% capacity utilisation. Now that we are going to import technology the example of DCL should be kept in view.

5.04 ***Revival Effort from Early Nineties :*** I was Managing Director of Durgapur Chemicals Ltd. (DCL) from March 1990 till December 1997. When I joined the organisation in March 1990 all the units of DCL were closed. Failure of timely and proper maintenance resulted in extensive corrosion and erosion of the structure. Emission of chlorine gas had expedited the process. The entire complex had a look of a mammoth grave yard. The experts had clearly spelt out that it would not be safe to try to run the units without complete civil renovation of the structure.

5.05 A question naturally crops up how and why the units of the organisation virtually crumbled down? Was there any defect in operation ? Was maintenance neglected ? Was it due to personnel problem? Was it a case of management failure? It may not be proper for me to suggest the answer as I am totally against predecessor hunting. But enunciation of the background would reveal that all the conceivable lapses were committed and in short it was a classical example of management failure.

5.06 : Durgapur Chemicals Ltd. was set up in 1963 with reasonable hope that the organisation would manufacture the basic chemicals. The availability of basic chemicals at this convenient industrial centre would induce a chain of chemical industries based on these basic chemicals. The necesary raw materials were expected to be available at Durgapur itself. Technology was to be imported.

The hopes were belied as the technology of one of the units (Phenol Plant) was outdated from the very beginning and capacity utilisation of this vital unit never exceeded 20%.

There was inordinate time overrun and consequential cost overrun and the units were not set up according to the sequence they were planned. This disturbed sequence and cost overrun had a disastrous effect on its viability and the organisation failed to earn profit even for a day.

5.07 Outline of the original programme : In 1963 Durgapur

Industries Board started execution of the Plan. Prior to that on 17.8.62 a consultancy agreement was finalised with Krebs Cie Paris. According to this agreement Krebs Cie Paris took charge of drawing, design, planning and engineering of the new units. According to another agreement they took the responsibility of supplying all the plants and machineries in accordance with Indo-French Credit Terms.

At that time following Plants were scheduled to be set up—

Caustic / Chlorine Plant

Phenol Plant

Phthalic Anhydride Plant

Pentachlorophenol Plant

It was an integrated scheme. Phenol Plant was conceived as the mother plant. Pure salt was scheduled to be prepared in Phenol Plant as a by product. This salt would be the raw material for Caustic Chlorine Plant. Excess chlorine manufactured in Caustic Chlorine Plant would be used for manufacture of phenol, monochlorobenzene being the intermediate product. By the time the Salt Preparation Unit was ready the Caustic Chlorine Plant could not be set up and the Salt Manufacturing Unit was totally corroded before Caustic Chlolrine Plant came into stream. The much needed integration was disturbed even before the Plant started production. For Caustic Chlorine Plant salt had to be procured from Gujarat and cost of freight was more than the price of salt.

In our country unfortunately we are more interested in postmortem reports rather than to take appropriate timely action.

6.00 Findings of Enquiry Commitee

6.01 When Durgapur Chemicals Ltd. failed to function according to original programme an enquiry committee was set up in 1967. The main findings of the Committee were :

Consultancy fee was too high.

The Project Report was not prepared properly, it could at best be considered as work programme, not a project report.

Time overrun resulted in cost over run and the foreign firm had to be paid more as consultancy fee.

The responsibility of the foreign firm was not properly specified before placement of order. Hence they could not be held responsible for the malady.

The plants were accepted without proper trial run.

While the plants were scheduled to be commissioned by 1965 they were actually commissioned in 1970.

According to the project, the pure salt for caustic plant should be available as by product of phenol plant. The salt recovery unit was corroded even before the entire plant could be commissioned.

The Phenol Plant was sick since inception.

Phthalic Anhydride Plant had no technical problem initially but inadequate supply of raw material and difficulty to procure catalyst were some of the problems of this unit.

Caustic Plant faced some technical problems.

Chlorine disaster damaged a number of equipments & instruments.

6.02 : ***Consequential Problem :*** The finding of the Enquiry Committee revealed the basic points of initial maladies of Durgapur Chemicals Ltd. Thus the dream child of Dr. B. C. Roy suffered a set back and the dream could not be realised. For more than two decades thereafter Durgapur Chemicals Ltd. failed to recover from its early ailments. The records reveal that selling price of its various products failed to recover even the variable cost of raw materials. Thus it reached an unenviable position where " the more it produced, the more it lost". It was not possible for DCL to mobilise fund for maintenance of equipments and

timely procurement of raw materials. At times it could not also pay the salaries and wages of its employees in time.

Although handsome subsidy was available from the administrative dept. it could not cover the cash losses. Electricity is the most important and costly raw material of Caustic Chlorine Plant. Since inception DCL failed to pay electricity bill of Durgapur for 8/10 years. State Govt. went through the exercise of paper adjustment by sanctoning few crores of rupees as additional loan to DCL and adjusting the amount against unpaid interest of Durgapur Projects Ltd. At that time Durgapur Project and Durgapur Chemicals Ltd. were under the same administrative Dept. Unpaid bills to DPL was utilised by DCL to meet part of its working capital requirements. Although profitability of DPL was not affected by this arrangement, their liquidity problem aggravated. This became more acute for DPL when it also started incurring cash loss.

6.03 *Grave Crisis :* No organisation can run under such circumstances and in early 1989 all the units of DCL had to be closed down. By that time the entire civil structure of all the units were about to collapse and it had a look of a graveyard.

6.04 ***Revival programme :*** In 1987-88 a 4 member Task Force Committee was constituted to examine the possibility of revival of DCL. The Chairman and another member of the Committee were reputed technologists; one member was a Chartered Acctt. and I was the Member Secretary of the Committee. At that time I was Secretary of Public Enterprise Cell of Govt. of W. Bengal under the administrative control of Development & Planning Dept. The role of public enterprise cell was similar to that of Bureau of Public Enterprises of Govt. of India.

At that time the general impression was that the DCL had no future and any effort to revive it would be a wastage of fund.

The Task Force Committee examined a report prepared by me earlier as Secy. of Public Enterprise Cell and based on examination of all previous reports and records, after a thorough

probe, the Task Force Committee submitted its report. The Committee identified the following as the problem areas of DCL :

Products of DCL were of poor quality.

The prices of products were ridiculously low.

Raw materials were produced at high price.

Output-input ratios were low for all the units

There was an unaccounted for gap between production and sale of chlorine.

Officers and workers were equally demoralised.

The Committee submitted its specific recommendation for revival of DCL. The cost of revival programme was above Rs. 48 crores. The programme included stabilisation of the existing plant, modernisation of some of the units and diversification of products.

The Committee suggested that the Board of Directors of DCL should consist of only professionals, and persons with professional qualifications only should be inducted in the management of the organisation. The idea was to remove from the Board some political persons who in league with unscrupulous managers of the organisation were exploiting DCL. The management of DCL was a divided house. Instead of work culture there was culture of intrigue and conspiracy. The result was inevitable downward trend in all spheres of activities.

7.00 : THE CHALLENGE.

7.01 : In this scenario in 1990 when I took over charge as Managing Director we had to start form the very beginning. I took over the challange of rehabilitating DCL from this stage at the fag end of my career.

The recommendations of the Task Force Committee were accepted by Govt. and Chief Minister readily agreed to reconstitute the Board of Directors with professional persons only.

The Board of Directors and the Management worked with perfect unision and there was no lack of co-ordination. In top management position vacancies were filled up with professionally competent persons and the selections were made through public enterprise cell.

7.02 : ***Renovation of civil structure with new technology :*** Our first priority was renovation of civil structure. This itself was a challenging task. The structures were corroded since they were exposed to chlorine atmosphere. Even though we had the programme for eliminating emission of chlorine in the atmosphere we had to plan preventive measures so that the new structures could withstand a certain degree of chlorine in the atmosphere. We appointed Shri S. Banerjee, the original architect of DCL and a reputed authority on concrete and structural engineering as our consultant. We were formally advised to appoint him by experts of Jadavpur University who conducted an on the spot survey. I got the assistance of Jadavpur University through Prof. Sankar Sen who was till then the Vice-Chancellor of the University. The experts submitted a written report depicting the precarious status of the civil structure. About technology to be adopted for renovation of civil structure we obtained the advice of experts of Jadavpur University, Indian Institute ofTechnology, Kharagpur and Regional Engineering College, Durgapur. We used a polymer based technology and we invited limited tender, as advised by Sri S. Banerjee, from parties having expertise on this technology.

Civil renovation work started by end of 1990. By June 1991, Caustic Chlorine Plant could be recommissioned, while Monochlorobenzene Plant was revived in Feb. '92 (Phenol Plant had to be abandoned earlier as it had failed to produce more than 15 to 20% of installed capacity. But Monochlorobenzene Unit of Phenol Plant was capable of running satisfactorily). Thereafter civil structure of Pentachloro Phenol Plant, salt godown and other essential parts were renovated. The new technology was costly but it could extend the life of the structure. The renovated structure had already lasted for about a decade without substantial expenditure for further maintenance. Initially when we started

the renovation, doubts were expressed about its efficacy from certain quarters pointing out that the cost of renovation was higher than the traditional cost of civil maintenance. However, much higher rates were offered by reputed firms before we went in for technological analysis by I. I. T., Kharagpur, Jadavpur University and Durgapur Regional Engineering College. These reputed firms had offered civil renovation on turn-key basis.

7.03 : ***Determination of priority in revival programme in view of limited fund availability:*** Although the Task Force Committee had recommended immediate investment of more than Rs. 4800 Lacs, in 7½years we got in driplets around Rs. 750 Lacs as Govt. was passing through acute fianancial crunch. Hence the diversification programme could not be implemented at the initial phase. Our emphasis was on stabilisation of existing units. We could not renovate the Phthalic Anhydride Plant as the feed stock of Napththalene had become obsolete and capital cost involving change of technology was around Rs. 2500 lacs and we did not have the required finance.

With limited availability of fund we concentrated on priority areas as identified by the Task Force Committee.

8.00 Concrete Steps Taken :

8.01 : ***Improvement of quality of products :*** Caustic Soda lye previously manufactured by DCL had concentration of around 30%. Most of the major end-users of the product need Caustic Soda Lye of higher concentration - of the region of 45-47%.

With existing technology by improving skill we could grudually improve the concentration to around 47% and could increase our market base enabling increase in production of Caustic Soda.

The quality of Monochlobenzene of DCL could be improved and the quality was accepted as one of the best in India. Almost the entire market of Monochlorobenzene is located in Western and Southern India. There are manufacturers of Monochlorobenzene in western India. Even then DCL is successfully

marketing the product in western and southern India, primarily on account of its improved quality.

8.02 : ***Marketing and pricing policy :*** I have earlier mentioned that the Task Force Committee had observed that price of products manufactured by DCL were ridiculously low. In fact the Committee had established with facts and figures that price of caustic soda lye and liquid chloronine of DCL were lowest in India; this was one of the major contributing factors for the loss incurred by DCL since its inception. One of the reasons of low price was poor quality of products. There may be other reasons as well. I do not want to spell them in black and white. We could fetch from the market the usual market price which was about 70% higher than the price at which DCL used to sell its products.

8.03 : ***Price of Raw Materials :*** The Task Force Committee observed that DCL purchased raw material at very high price. The major raw materials required by DCL are electricity, benzene and salt. The price of electricity is determined by DPL and State Govt. We arranged some concession in Power tariff and this will be discussed later. DCL procured benzene from Steel Authority of India Ltd. (SAIL) where the price is fixed. We could later get the benefit of substantial reduction of price from SAIL by enlisting ourselves as bulk consumer, and after establishing that we were in a position to make prompt payment. The Task Force Committee held DCL responsible because DCL had been purchasing salt from middle men and there was considerable cloud regarding those transactions.

We introduced the system of press tender directly from manufacturers of salt. The tender evaluation committee consisted of top managers of operation, maintenance, finance and laboratory. All these transactions before finanlisation, were placed before Board of Directors. At the moment the landed price of salt, purchased by DCL compares favourably with the price at which other manufacturers of this region are purchasing salt.

8.04 : ***Raw Materials Consumption:*** The Task Force Committee had rightly observed that output-input ratio for all

the products of DCL were very low. As a result, DCL consumed more raw material than it was technically required. This increased the cost of production and was a major contributing factor for incurring loss.

After persistent efforts our consumption of salt came down from 2.2 MT. to 1.7 MT for production of 1 MT. of caustic soda. Average consumption of our competitors in India was 1.8 MT. Theoretically it is possible to reduce the consumption upto 1.6 MT. But sodium chloride content of salt that we receive was not 100% and our consumption was not higher than our competitors having more modern technolgy.

Consumption of power came down from 4200 KWH to 3400 KWH for production of 1 MT of caustic soda. This included consumption of auxiliaries. Our reduced consumption was at par with all India averge taking into account auxiliary consumption. If we could switch over to membrane cell technology the consumption could be brought down to below 3000 KWH level. We did not have the requisite fund for incurring the capital cost and taking into account cost of capital, the gain would not have been substantial unless we could get the fund at substantially low interest rate.

In Monochlorobenzene Plant our consumption of benzene came down from 0.9 MT to 0.76 MT for production of 1 MT of MCB against theoretical optimum level of 0.73 MT.

Reduction of level of consumption of raw material saved around Rs. 3 crores per year at optimum production level.

8.05 : ***Gainful utilisation of co-products / by-products :*** The Task Force Committee had observed that there was an unaccounted for gap between production and utilisation of chlorine. According to chemical equation, along with production of 1 MT of caustic soda, 0.88 MT of cholorine is manufactured. Our liquefaction plant could liquefy upto 80% of chlorine into liquid chlorine. Hence, as co-product of 1 MT of caustic soda, production of 0.88 x 0.8 = 0.7 MT of liquid chlorine is feasible.

Previously compared to caustic soda only 40% of liquid chlorine could be recovered. We could increase the recovery to 68 to 69%, i.e. very close to the optimum level of 70%. Remaining gaseous chlorine were mixed with lime in hypo tower and were released in the atmosphere. With liquefaction of about 80% chlorine produced, the quantity of unliquifiable gas was reduced and for utilising the balance gaseous chlorine we set up a new Hydrochloric Acid Plant of appropriate capacity and thus utilization of chlorine improved from 50% to more than 98%. Moreover this has added flexibility of the plant. When the demand of MCB and liquid chlorine are more, we are liquifying chlorine upto maximum capacity, while when demand for hydrochloric acid increases we produce more hydrochloric acid. This also depends on the price that we get for liquid chlorine, MCB and hydrochloric acid. In chemical industry these prices vary rather abruptly. Hence, such flexibility is commercially advantageous. Since we are using waste byproducts as raw material of HCL the entire sale proceeds of HCL is adding to our contribution. On the other hand the annual expenditure of around Rs. 50 lacs to buy lime has almost been eliminated. Thus the pay back period of the new hydrochloric acid plant was only 8 months.

9.00 : Pentachlorophenol Plant :

9.01 : In our country, till now market potentiality of liquid chlorine is somewhat limited. 70 to 75% of chlorine produced are being utilised to manufacture MCB. The balance chlorine is sold to water works, paper industry power plant.

Pentachlorophenol (PCP) plant was renovated to use more chlorine for captive use. According to guide lines of Environment Dept., use of PCP in various industry has been restricted. Hence we have switched over to sodium pentachlorophenate (SPCP) for which adequate market is available. We are also manufacturing monochlorophenol (MCP) to meet requirement of some central sector industries located in West Bengal.

10.00: Profitability of DCL

10.01 : We have been able to rectify all the maladies pointed out by Task Force Committee. The only other point is regarding morale of officers and workers. With improved performance we have virtually eliminated annual cash loss of around Rs. 6 crores and this boosted morale of our employee.

10.02 : ***Cash payment to DPL on account of Electricity charges:*** As mentioned earlier DPL did not get any payment from DCL against supply of electricity. In 1991 we negotiated a deal with DPL to get electricity at concessional rate on condition that DCL would clear the current bills within the time limit of the bill and would pay the arrears in instalments. Similar concessional tariff was then allowed to other industries of similar nature by State Electricity Board and CESC. This tariff was substantially higher than the amount received by DPL from WBSEB (who drew 70% of the electricity produced by DPL)but was lower than the tariff of other industries whose load factor was substantially lower than ours. DCL started making payment of current dues from June 1991 when it resumed operation, and did not default in making timely payment thereafter. At that time arrear dues on account of unpaid electricity in past 7/8 years amounted to around Rs. 8 crores. We started payment of arrear dues from 1993 and it was agreed to repay the arrear dues in 10 years. After $3^1/_2$ years our arrear dues came down to below Rs. 5 crores. Thus we could reduce the arrear dues by more than Rs. 3 crores in $3^1/_2$ years. This allowed DCL breathing time in its rehabilitation process. DCL also sold its products required by DPL (caustic soda, chlorine, hydrochloric acid) at substantially concessional price and supply of all these materials were also adjusted against their arrear dues. This was advatageous for DPL as well since they received cash payment of electricity and arrear dues, while under prevailing arrangement they used to get payment from Govt. only on paper and their liquidity was severly affected. All the payments to DPL were made from the fund internally generated by DCL. From 1997 DPL sharply increased

the tariff including arrear dues on account of fuel clause surcharge and a dispute cropped up. We had referred the dispute to our administrative Dept. but continued the current payments. I left DCL in December 1997. I am still a Director of DPL. According to my information since my departure virtually no cash payment was made to DPL on account of electricity from its internal generation of fund. Cash loss has also started increasing. Thus the situation has returned back to square one. Yet DCL most certainly has the potentiality of attaining viability within a short time unless the price of the products nosedive and electricity charge increases steeply.

11.00 : ENVIRONMENTAL PROBLEM :

11.01 : Protection of environment is essential in the interest of health and safety of our future generation. The industries had been merrily polluting the environment, and directions of West Bengal Pollution Control Board were being disregarded with impunity. The Pollution Control Board had determined rigorous standard for the effluent the industries were permitted to discharge. Many of the industries did not have the financial capability to set up new effluent treatment plant and Pollution Control Board was unable to enforce its directive. The industries knew the ways to disregard the Board.

A public interest litigation was filed in Hon'ble Supreme Court. The Hon'ble Court issued appropriate order but even then some of the industries did not have the financial capability and or technical competence to act according to the order and they faced the threat of closure.

11.02 : ***The extent of problem of DCL :*** The mercury content of the effluents of DCL was two (2) part per million (PPM). We were ordered to achieve a standard of 0.01 PPM. It was a tall order. We had a mercury recovery system with ion-exchange method. But it was not used for a long time. We renovated the unit and consulted with all technical people of the organisation irrespective of their hierarchial position in the organisation,

including the representatives of workers union. After renovation of mercury/recovery system the mercury content of our effluent came down from 2 PPM to 0.06 PPM.

11.03 : ***The next phase of our effort :*** Although it was a substantial improvement we were far behind the target. But we could substantiate the authenticity of our efforts before Hon'ble Supreme Court and Court allowed us more time (2 months) to achieve the norms. By this time we had identified the technical programme required to achieve the norms. We found that the sludge of our clarifier contained mercury of 15 PPM and till then no technical process was invented within the country to economically recover this mercury from the sludge. Hence we prepared concrete tanks of appropriate size to store the sludge so that it did not go anywhere else. In future, if possible, we could recover mercury from the sludge. We also analysed the mercury content of effluents coming out from different parts of the plant. The effluent of which content of mercury was less than 0.01 PPM was allowed to go out of the plant. For effluent which still contained more than 0.01 PPM of mercury, we renovated the drain within our factory. The process of mercury recorvery was repeated and the effluent content went below 0.01 PPM. Thus ultimately within the scheduled time the mercury content of our effluent came down to 0.008 level. Our analysis was confirmed by the analysis of West Bengal Pollution Control Board and other independent authority and we were open for inspection by any other authority as we were sure that we had scientifically achieved the norms. The total expenditure was only a few lakhs of rupees and we could get this amount by recorery of mercury from the mud of our drains which we had renovated.

11.04 : ***Follow-up action :*** Regarding follow-up action we did not keep any scope of doubt. We regularly arranged to analyse the result *every day* and the result became a part of our management information system. We sent our analysis report for all these days at regular interval to West Bengal Pollution Control Board and they verified our analysis whenever they liked. Thus we could establish that where there is a will there is a way and it

is not always necessary to engage consultants as the system has almost turned out to be a racket.

11.05 : Removal of HCl from effluents : In our MCB and PCP Plants considerable quantity of hydrocholoric acid were produced as byproduct. They were of relatively low concentration and had no buyer. DCL used to throw this scarce commodity in the drain and thus polluted the effluent. When pollution control had the directive of Hon'ble Supreme Court such soft method of disposal was no longer feasible. Hence we devised ways to improve concentration of byproduct HCl and could sell them to traders at a price of about 70% of the price of synthetic hydrochloric acid manufactured in our caustic chlorine plant. Although we improved the concentration it still contained benzene or phenol in PPM level. Hence these were not sold to power plant for their demineralisation unit or water works for purification of water. These could be used for cleaning the floor and for similar purposes.

Thus pollution of effluents could be totally stopped and we added considerable additional revenue without any additional expenditure.

Since we could increase utilisation of chlorine of Caustic Chlorine Plant from 50% to 98.5%, air pollution could be eliminated; whatever chlorine remained could be easily neutralised with lime.

11.06 : In my humble opinion for most of the chemical industries it is possible to improve environment by more and more useful utilisation of wastes. In this regard DCL could be considered as a model.

11.07 : Environment control may not be that simple for some other industries where special arrangements may be necessary. The nation cannot perhaps afford to close down industries which would not be able to meet, the norms prescribed by Pollution Control Board. Important questions are to be answered — what

will happen to the workers of these industries? Will it not affect the economy of the nation as a whole?

When I was in Science & Technology Deptt. more than a decade back, the British Council of Calcutta had organised a two day seminar with experts of Pollution Control from U.K. They frankly admitted that England could not afford to keep all the rivers clean. Moreover, they are not so particular about prescribing rigorous standard for the effluents. On the other hand they ensure that the effluents are not released at the bank of the river. The industries are compelled to carry them upto midstream. They also compel the industries to add some chemicals in the river to react with some of the pollutants they ultimately discharge.

12.00 : Immediate diversification programme of DCL :

12.01 : With limited financial resource available to public enterprises I did not consider it prudent to go in for heavy investment in Capital Intensive Plants. In the present scenario of uncertainity all around, Capital Investment need be planned with due care and caution. In DCL we had so far gone on for Capital Investment where pay back period is 1 to 2 years. If any project shows pay back period of 5 years or more I feel apprehensive about ultimately achieving viability, as time over run and cost over run cannot always be controlled inspite of best efforts and the price of the products are always volatile.

12.02 : In our country even now capacity to sell chlorine determine utilisation of Caustic Chlorine Plant. We could increase capacity utilisation from 40% to 98% as we could capture increased share of chlorine market. Bulk of our chlorine is being utilised to manufcture MCB. We sell this product in western and southern India and have to compete with the manufacturers located in this regions. Expansion of capacity of MCB by other manufacturers gives a warning that it may not be prudent to expect that we would continue to retain our present market share of MCB after a few years. We are, therefore going in the diversification of products, a 15 TPD bleaching powder plant is being installed and the project is in advanced stage.

12.03 : The HCL unit which we had recently installed is using not only chlorine but also a portion of hydrogen produced in the electrolysis process. We have taken a project of purifying and selling the surplus hydrogen gas for further improvement of our economy.

12.04 : As mentioned earlier switching over to membrane cell has been kept in view. This would depend on availability of fund.

12.05 : Revamping of our phthalic anhydride plant would most certainly improve our economy but this also depends on availability of fund and technology at reasonable cost.

This was the situation when I left DCL. Achievement of viability was clearly within sight along with restructuring of our capital based on the present market value of our assets.

13.00 : The problems faced by Caustic Industry from 1997 onwards :

13.01 : DPL did not want to supply power at old concessional rate. They continued a concession, but the rate was increased abruptly.

13.02 : As a result of globalisation of industry caustic soda were dumped in India at low price.

13.03 : Some of the foreign countries could afford to dump caustic soda in India, at low price as in their country the main driver of the industry was not caustic soda but chlorine and electricity cost in those countries was much lower than in India.

13.04 : Since the problem was faced by all the alkali manufacturers of India, at their instance a detailed study was carried out by Tata Economic Consultancy Service (TECS). Their report was submitted on 4th November, 1997 and I left DCL on 31st Dec, 1997.

14.00 : THE INTRODUCTORY POINTS OF THE REPORT OF TECS:

14.01 : Chloro Alkali Industry in India is perhaps the oldest segment of the chemical process industry in India. Over last five

decades the industry has demonstrated a clear and faultless track record of serving as a backbone/mother industry to development and growth of several downstream industrial sub-sector.

14.02 : The industries that grew up around chloralkali sector are :

Soap and detergent industry,

Pulp and paper industry,

Textile processing industry,

Aluminium smelting,

Dyes and dye stuff industry,

Rayon grade pulp.

14.03 : Caustic soda, one of the three principal inorganic building blocks (the other two being — soda ash and sulphuric acid) is the principal product of chloralkali industry in India. Chlorine, which is a co-product of the industry has emerged from the shadow of the past to assume growing importance and serves as a principal intermediate in the manufacture of TVC, one of the 5 major thermo-plastic commodities.

14.04 : Chloroalkali industry currently (Nov. 1997) finds itself in dire state. The fortune of the industry in last year or so has taken a severe beating.

14.05 : The near crisis situation has been principally precipitated about by the following two factors :

* A— Galloping cost of electric power.

* B— The severe threats of import. This has been caused by highly inequitous punishing pricing strategy adopted by overseas competitors.

Both these factors are clearly beyond the control of chloroalkali industry. Thus the industry has to suffer acute pains bordering to gloom and despondence for no fault of its own. The situation clearly calles for Govt. intervention in one form of the other.

15.00 : Historical background :

15.01 : Caustic Soda industry is a Rs. 3600 crores strong one. It is an industry which produces caustic soda, one of the 3 most prominent inorganic building blocks. Together with chlorine, which is co-product of the industry, caustic soda industry serves as mother hen to a wide range of industrial sub-sectors ranging from aluminium on one hand to pharmaceutical industry on the other. It is important to appreciate this multiplier impact of this industrial sub-sector on other end-using sub-sectors which it serves because it is significant.

15.02 : Caustic soda industry is one of the most important constituents of the chemical industry in India. Chemical process industry itself has a share of 12% (approx.) of the total industrial production and 15% (approx.) in the output of the manufcturing sector. Caustic soda industry itself directly accounts for 5% of the output of the chemical process industry. However, if one takes into account the multiplier and catalytic impact of the use of caustic soda and chlorine in the entire spectrum of end-using industry, the total output which comes under the influence of this industry accounts for roughly 15% of output of chemical process industry. Besides, caustic soda industry directly employs close to 5 to 7 lacs persons.

16.00 : Historical performance

16.01 : The production of caustic soda by the industry has increased fortyfold over the last 5 decades.

Demand of caustic soda has grown at the rate of 5 to 6% per annum from a level of 10,54,400MT per annum in 1991-92 to a level of 13,39,400 MT per annum in 1996-97. According to TECS the industry is poised to grow around 7% with demand touching 16,40,800 MT per annum by the turn of century subject of course that there are no strategic hurdles to the growth of market and industry in India.

16.02 : *The problem* :

The following scenario depicts the problem facing the industry. It is caught between the devil and the deep sea.

Item	Year 1991-92	Year 1996-97	Remarks
Cost of power	Rs. 1.5/KWH	Rs. 2.8 /KWH	Extent of growth 87% over last 5 years
International Price of Caustic Soda per MT	US$ 400.00	US$ 160.00	Decline of 60%
Import duty	Rs. 3500+45% +5%	30%	A reduction of 66%

17.00 : ANALYSIS OF THE PROBLEM :

17.01 : *Industry driver — chloroalkali in global market*

The global chloroalkali is driven by chlorine in global markets while in India caustic soda is the main driver. Because of such structure of the industry, chlorine recovers most of the costs of chloroalkali production globally (and so caustic can be even priced at a negative contribution).

In India caustic soda is a main product for the chloroalkali industry and chlorine is treated as a byproduct. Chlorine, therefore, hardly contributes to realisation of total cost. With chlorine prices being low, caustic soda has to realise more than 65% of the production cost for chloralkali plant to be economically viable.

17.02 : Globally the price of caustic soda bears no relation to the cost of manufacture but it is dependent on perceived imbalance between the demand and supply. The price of caustic soda is seen to vary from a low of US$ 30.00 per tonne to high of US$ 350.00 per tonne over a 7 to 8 years cycle. Consequently the prices do not reflect efficiency of caustic soda manufacturing.

Globally when caustic soda is in over supply, producers compete fiercely with each other for markets driving down their profitability. When chlorine is in over supply, the competition is much less severe, so profitability is not under cut. In essence the producers understand that little extra chlorine will be sold if the price is dropped. So chlorine market resist the temptation.

17.03 : ***Cost of power :*** Amongst the major threats for the Indian industry, Saudi Arabia is known to have low cost of input like electricity and capital.

China engages a similar activity by not using the nominative costing principle which have assumed acceptance worldwide and by charging abysmally low rates of electricity. In Fujian province the rates are as low as Rs. 0.47 (13 cents) per KWH. As a result these countries would invariably have price advantages over their competitors which are not due to efficient manufacturing . In India cost of power is about 66% of the operational cost of producing caustic soda. The electricity cost for plants in India is on average Rs. 2.80 per KWH. while it is 78 paise in Saudi Arabia, Rs. 1.02 paise in China and Rs. 1.80 p. in USA.

17.04 : ***Financing cost — high in India :*** For a plant of 1500 TPD of caustic soda capacity with estimated 95% capacity utilisation the capital cost is Rs. 1350 crores (as in Nov. '97). Interest rate in India is 17%. Interest rate in USA is 8.5%, that in Saudi Arabia & China are 7% and 13% respectively. Interest cost per tonne of caustic soda is Rs. 3,253.50 in India, Rs. 1626.79 in USA, Rs. 1339.71 in Saudi Arabia and Rs. 2488.00 in China.

Saudi Industrial Development Fund, a state owned financial institution has been known to provide funds towards project financing at abysmally low interest rates (sometimes even interest free).

With such a cost disadvantage for domestic chloroalkali manufacturers even the most efficient manufacturers are finding it difficult to compete with imports.

17.05 : On apportioning the cost of manufacture to caustic soda and chlorine based on production norms of 1 tonne of chlorine for every 1.1 tonne of caustic soda, the cost per tonne of caustic is indicated in the table below :

Cost of manufacturing caustic soda :

Caustic Soda -Rs. per ton	U.S.A	Saudi-Arabia.	China	India
Without R.O.I.	5952	4669	6269	10163
% age variation over manufacturing cost with R.O.I. in India	(-)41.4%	(-)54.1%	(-)38.3%	—
With R.O.I. of 15%	6711	5429	7028	11159
% age variation over manufacturing cost with R.O.I. in India.	(-)39.9%	(-)51.4%	(-)37%	—

(Figures taken from the report of TECS of Nov. 1996)

17.06 : Conversion to membrane technology will substantially reduce energy consumption by about Rs. 600/KWH per MT but would require substantial capital cost.

18.00 : Global Players of Caustic Soda

18.01 : ***Saudi Arabia :*** Saudi Arabia is estimated to have a capacity to manufcture 590000 tpa of caustic and chlorine capacity of 536000 tpa. The local chlorine produced is meant for domestic consumption for manufacture of VCM, EDC, Titanium Di-oxide etc. whereas domestic caustic demand is estimated to be 70000TPA. This leaves a large surplus of 520000 TPA (88% of the capacity) of caustic for export. With a chlorine-driven capacity in Saudi Arabia the producers have a strong incentive to engage in dumping caustic soda in the market.

18.02 : ***China :*** China has estimated chlorine capacity of 27,49000TPA and caustic capacity of 30,04000TPA. With 100% consumption of chlorine in the domestic market China has about 40,0000 TPA of caustic soda which can be exported.

18.03 : It is estimated that approximately 6 million TPA of caustic capacity world wide would be added by the turn of the century. Of this 2 million TPA would be in Asia. This includes addition of 0.78 million TPA in India. The Indian programme is unlikely to be implemented if the current trend of import persists.

Most of the new capacities announced involved captive consumption of chlorine for PVC production. This would lead to a flood in caustic supply in the market leading to lower caustic return. The global players with chlorine recovering most of the cost of manufacture would not be worried about dumping the caustic in market, India being one of the major targets.

19.00 : Need of Level Playing Field :

19.01 : The Indian caustic industry with annual turnover in the region of Rs. 3600 crores need support from Govt. for its sustenance and survival. To prevent any dumping of caustic soda in the Indian market and ensure in industries' survival, a reconsideration of import duty is essential.

19.02 : The Indian chloroalkali industry is caustic driven. The nature of the industry is slowly changing to the global model. It will take 3 to 5 years till it can be considered to fully follow global model. This transformation is expected due to a tremendous surge of chlorine demand from PVC segment (presently it accounts for only 9% of chlorine consumption). This industry is apparently poised to change the complexion of chlorine consumption priorities in India and will mark the beginning of chlorine driven market.

Hence the chloroalkali industry needs to be provided a level playing field till such time by increasing import duty to 40% for at least the next 3 years. Because of the structure of the global chloroalkali industry, the major international players, when chlorine prices are high, resort to selling caustic in the market at below its cost price. In such a situation to safeguard the industry's interest anti-dumping duty should be levied.

19.03 : ***High Power Tariff :*** Power costs account for around 66% of the operational cost for manufacturing caustic soda. The major impediment faced by the Indian chloralkali industry in competing with the global players is the high rate of power in the country. The power tariff in India seem to range from Rs. 1.67 per KWH in Kerala to Rs. 3.85/KWH in Gujarat, the

weighted average being Rs. 2.82/KWH. The severity of the problem will be evident when we compare our tariff with USA, China & Saudi Arabia.

Comparison of Power Tariff in different countries

Countries	Average power rates (Rs. / KWH)
India	2.82
USA	1.80
China	1.02
Saudi Arabia	0.78

The trend of rise of power tariff in India is likely to continue. Hence the economics of captive power plant with reduced import duty may be closely examined. Till such time chloralkali sector deserves concessional power tariff taking into account their high load factor. The implication of high load factor is immense for a power generating industry. The economic implication of high load factor should be compared while allowing such concession.

19.04 : ***Technology :*** Membrane Cell Technology is best suited to tackle the high power tariff. Already around 30% of manufacturers of chloroalkali sectors in India have partly switched over to this technology. The technology may lead to almost 20% saving in power consumption. Here also concessional import duty for capital goods is required for conversion from mercury cell to membrane cell. It will be difficult for relatively smaller caustic industries to mobilise the fund unless low interest finance is made available.

19.05 : If these measures are not taken, the caustic industry is doomed to meet its natural death and the nation will be totally dependent on import of caustic soda/chlorine. Hence the benefit of physical export of caustic need be made available for deemed export to further the cause of import substitution.

20.00 : DURGAPUR PROJECT LTD.

20.01 : Durgapur Projects Ltd. (DPL) was the first big scale industrial project undertaken by Govt. of West Bengal to be operated by themselves. It was in 1961 that a company was formed. In 1953 when Late Dr. B. C. Roy, the then Chief Minister of West Bengal visited West Germany, Late Dr. B. C. Guha in a personal letter to Dr. B. C. Roy emphasized the fact that West Bengal had vast deposit of coal around Ranigung-Ondal areas and, as such, any major industry in West Bengal should be on a coal base. He mentioned that if the proposal met Dr. Roy's approval, Dr. Roy could discuss this with German experts.

Dr. Roy was quick in appreciating the suggestion and discussed the matter with Dr. Leizley, the then Managing Director of Dr. C. Otto & Co. It was arranged during the discussion that in lieu of certain fees, Dr. C. Otto & Co. would submit a feasibility report on a project containing Coke-oven and Power Generation Plant. Dr. Roy had visualised a smokeless Calcutta. His idea was to bring cokeoven gas from Durgapur to Calcutta and use this for industrial and domestic purposes. Dr. Roy also visualised that the cokeoven plant would form nucleus of chemical industries based on cokeoven chemicals. Production of Benzanol and Benzene were included in the Project Report that followed.

20.02 : DPL grew up as an industry for industries and supplied coke, power, gas and water to neighbouring industry. After few years the company started incurring huge losses.

20.03 : I was with Durgapur Projects Ltd. from 1973 to 1978 and could totally eliminate its loss. The organisation earned net profit. Unfortunately the position had again deteriorated and I have been re-inducted in the Board of Directors of DPL.

20.04 : I am not narrating the entire experience of sharp turn-around of DPL between 1975 and 1977, and not analysing the reasons for the subsequent deterioration of its performance. It will be sufficient to mention that the main improvement of its performance was in its power plants which not only produced much more energy but there was also a dramatic reduction of

consumption of fuel oil from more than 5000 KL per month to around 300 KL per month. This involved saving of crores of rupees and after this achievement there were two attempts on my life; once I was shot at and then I was hit on the head with a blunt weapon. Since all these relate to power plant and power plant cannot be regarded as a chemical industry I am not describing the experience in detail. The DPL also has a Coke Oven Complex which is a chemical industry. A tentative decision has been taken to merge the power plant of DPL with Kolaghat Thermal Power Station while the power distribution net work will be merged with WBSEB. Thus Durgapur Projects Ltd. will consist of only the Coke Oven Complex and Water works.

21.00 : The problems of Coke Oven :

21.01 : The byproduct plant is not being properly utilised to manufacture Coke Oven chemicals. The management incharge of operation of Coke Oven Complex have some explanations to offer. According to him the Tar Distillation Plant of DPL is based on vacuum technology only and this is not sufficient for satisfactory tar distillation. His statement requires technical scrutiny.

21.02 : *Benzol Recovery Unit* is not working. It is argued that the original manufacturer of Coke Oven Plant, i.e. Karl Still had recommended use of high volatile coking coal. This would make recovery of benzene smooth. It is claimed that M/S. Otto India have modified the plant and recommended use of coal with less volatile content. This has improved yield of coke but benzol recovery is no longer possible. This statement has to be technically scrutinised since importance of recovery of cokeoven chemicals is immense.

22.00 : Role of Administrative Dept.

22.01 : DPL is under administrative control of Power Deptt. and substantial fund has been invested to renovate the power units. Since a policy decision has been taken to separate the Coke Oven Plant and Water works from the Power generating & Transmitting Units, no major investment decision is now possible

for them for renovation of Coke Oven Complex. DPL was originally conceived as an integrated unit. Hence before implementing the decision careful examination of the implication is required. A committee is looking into it. I feel that at this stage attention for renovation of Coke Oven Complex is all the more necessary as the economics of the left over units has not been properly studied.

22.02 : *The problem of marketing coke produced in DPL :* Coke produced with Indian coking coal has high ash content and has a limited market. Some of the steel plants are preferring to use more and more imported coke as they have less ash. In this scenario it is necessary to probe deep into the future of DPL. It has to be examined whether low ash content coking coal available in Assam can be utilised. This coking coal has some sulphur content. Therefore, only a certain percentage of the coal can be used. It is also to be examined whether importing coal and then converting the coal in DPL's idle Coke Oven Plant (only a small fraction of its capacity is now being utilised) would be economic and whether it would be able to compete with imported coke.

22.03 : For more than last 8 years I was with Board of Directors of DPL. A Board Committee was constituted to economise the problems of Coke Oven group of plants. I was one of the members of the Committee. We have submitted a report for revival of the Coke Oven Plant and coal washery. We are not sure whether Govt. would act on our recommedation.

23.00 : CONCLUSION :

23.01 : I have mainly discussed about DCL and have tried to depict the overall picture of the problems of the entire caustic chlorine industry since this is one of the most important building blocks of chemical industry.

For Coke Oven plant, if full utillisation of all the by-product plants could be achieved more and more industries could be attracted towards West Bengal for utilising these value added coke oven chemicals. By-product plants continue to remain a

neglected area definitely for DPL, and I am not too sure whether the by-product plant of other coke oven plants under steel plants are taking any steps for proper recovery of the coke oven chemicals for further growth of chemical industry.

23.02 : I have a feeling that the price of products of a number of chemical industries fluctuate too frequently and too abruptly to plan for the future with confidence.

23.03 : Before I conclude, I reiterate that I am aware of my limitations — but I do hope that once the issues are raised they would initiate discussion, if not to-day, but may be later and this may be helpful for chemical industry as a whole to march forward.

V - 5

NATIONAL PROBLEMS AND MANAGEMENT OF THE RIVERINE SYSTEM IN THE EASTERN INDIA

SUNIL SEN SARMA

Introduction

Land, water and people go together. With variable physical characters, land has a locational discreteness. So also, to some extent, the people tend to be rooted to their settlements, conditioned by physical environment, culture, profession, livelihood and traditionality. The rivers with their characteristic wandering pattern establish a linear strand and weaye an interacting physico and socio political fabric, with animate and inanimate elements, transcending natural and man made artificial boundaries. When any one of this interwoven warp and weft of the fabric is plucked, every other strand of it gets affected. This is not just metaphorical. A river with ideal flow regime is a rarity in nature, and problems are inextricably associated with it. The problem may emanate as a natural one, consequent upon the physical processes of a riverine system, or a socio political one, when a river is either put to use on regional interests alone disregarding those of other regions within the basin, or when any measure to prevent or control the negative effects on human settlements, like floods, are so adopted as to affect the natural processes. Needless to point out that the mode in which a river is used and technologies applied, are the

outcome of the human perception of a natural system in relation to his own. It is demonstrable that in amending a situation which has gone wrong with a river system in use by man, a paradigm shift is necessary in the concept of management in a bid to integrating the regionality with the whole. To understand this, it is proposed to deal with the river systems of Eastern India, as a part of the greater transboundary river systems of India, or for that matter, of the entire eastern part of this sub-continent. It is necessary for that to have glimpse of the systems, their nature, changes, historical trends and past and present perceptions on their uses.

The River System of Eastern India

On the regionalisation on political boundaries, as within India, the provinces of Bihar, Orissa and West Bengal may be said to constitute Eastern India. But on the basis of the concept of a river basin, the inclusion of Bangladesh cannot be left out of this consideration. Even the contiguous country of Bhutan is to figure as, at least, peripheral zone in the discourse. Of these, the case of West Bengal is crucial and cardinal enough to demonstrate and establish what has been said in the introduction.

Major part of West Bengal is situated within the Ganga basin, being 7.16 million hectares (m. ha) out of the State's geographical area of 8.875 m.ha., or 80.7% of the State's total geographical area. About 11.9% of the State's area lies within the Brahmaputra basin. Thus, except 7.4% of the areas at the south western part of the State, within the district of Midnapur, West Bengal is mainly situated within the Ganga and Brahmaputra basins. These two are amongst the largest basins of India, which occupy almost the entire northern and north-eastern part of the country.

In their planner disposition, nature of the basin, geomorphic set-up and geological process, the two rivers bear some similarity.

Ganga, after debouching into the plains from the high hills, flows from west to east for about 1800 km before turning south

east near Rajmahal in the West Bengal-Bihar border. The Gangetic plain is thought to owe its origin to a sag in the crust, probably formed contemporaneously with the uplift of the Himalayas starting in Upper Eocene period (about 45 million years before present). This sag or depression sandwitched between the Himalayas to the north and Vindhyan ranges, Central Highland, Chotanagpur and Ranchi Plateau to the south, has since been filled up by sediments derived from the mountains lying to the north and south of it, mainly from the lofty chains of Himalayas which are actively being eroded by the main rivers traversing them. The river is braided in the stretch upstream of Rajmahal with sandy channel bars, has for quite a long stretch upstream of this place rocky and stable southern bank and formidable tributaries from the high hills of Nepal joining the main stream at its north bank.

Brahmaputra, originating in Tibet disgorges into the plains of Assam after flowing through the eastern Himalayas for about 250 km. The river then flows from east to west for about 700 km. through a narrow valley nearly 80 km. wide, delineated by the Himalayan ranges to the north and the hill ranges of Nagaland, Cachar and Meghalaya Plateau to the south, then taking a sharp southerly turn enters Bangladesh to join Ganga after flowing for about 160 km. The narrow valley is believed to have formed in the shape of a trough by a series of parallel faults. This trough subsequently got filled up with the sediments brought down by its Himalayan tributaries. Combined sediments of Ganga and Brahmaputra formed the Bengal Delta, one of the largest deltas of the World.

The formation of delta takes place along a river at its tail end, where the gradient is flat, and hence the velocity is not sufficient enough to carry the sediments of the river. The sediments get deposited in the low lying areas, raising the land. The situation is aided by the tidal effect along the river channel, specially when the sediments carried by a river are more, volume of upland flow is less and gradient is flat. In the non-deltaic stretch, the gradient and hence the velocity is strong and if the

volume and flow of the river are maintained optimally, the channel remains in efficient condition. Even in deltaic region, the river spills over the banks to deposit the silts during floods and after depositing the silts, the silt-free spilled water flows down the channel in the subsiding stage, maintaining the efficiency of the channel. With time, both the silt receiving spill area and the river bed gradually rise, and the flood level within the channel also rises under this condition. At one stage the river breaks its banks, seeking lower levels, or in other words, attempts to establish new gradient in order to maintain the flow. Gradient, volume of water in a river section and amount of sediments — these three elements dictate the course of a river. Any change in one or all together causes the river to change its precise direction. Smallest alteration in the course has an effect which is felt for considerable distance above and below. The changes may be brought about by either natural processes, like initial ground slope, nature of rocks or ground materials along the course of a river, geological processes causing ground movements and dislocations, excess of hydrological inputs following climatic changes etc., or human interference like tinkering with the river, reducing the flow of river by large scale withdrawal of water, specially during the low flow period, bringing about the changes in the landform, vegetative covers in the watershed by wide scale deforestation, extensive disturbance of landform, which result in rapid run-off, intensive denudation in the catchment basin and enhancing supply of sediments in the rivers etc.

Perturbations of river regime greatly affect the tract through which it flows as well as the population. In case of the rivers of Ganga and Brahmaputra, historical records prove how the vast populous areas of eastern India were affected by such changes along the river courses.

Changes in the courses of the rivers and associated social effects :

In the eastern part of India (including that of the present Bangladesh, on consideration that this also constitutes the lower

part of the Ganga-Brahmaputra basins), the historical records of last three to four centuries indicate that natural changes in the courses of Ganga and Brahmaputra mainly affected (i) the North Bengal due to the diversion of Tista, towards the end of the eighteenth century, (ii) portions of Mymensingh and Dhaka districts of Bangladesh, due to the diversion of main Brahmaputra through the present Jamuna channel in Bangladesh in the earlier part of the nineteenth century, and (iii) central Bengal due to the avulsion of the Ganga through the Padma channel, sometimes in the sixteenth century. (Majumder, 1942).

Past records in the form of maps prepared more than a couple of centuries back and evidences on palaeo channels and nature of sediments etc. emanating out of the studies in earth science, led some authorities to believe that the North Bengal plains were originated and flourished by the sediments brought down by the Koshi, Tista and Brahmaputra, which used to flow through North Bengal at times during their life cycle before assuming their present configurations. Koshi receded further west, Brahmaputra further east and Tista from southward direction, as a tributary of Ganga, towards east joining Brahmaputra. The latter flowing in three distinct courses along Punarbhaba, Atrai and Karatoya and coalescing with Mahananda lower down used to join Ganga near Jaffraganj near Goalundo (now in Bangladesh). Following a very high flood in Tista in 1787, it was diverted through an old abandoned river course eastwards to join the present course of Brahmaputra near Bahadurabad (in Bangladesh). The main channel of Brahmaputra till then used to flow south-eastwards past the high older alluvium tract of Madhupur Jungle in Mymensingh district, and the present north-south course west of Dhubri in Assam was a stream of minor importance, probably the Konai-Jenai, which was presumably a spill channel of Brahmaputra. Secular changes were taking place in the headward region at the extreme north-easterly catchment of Brahmaputra. Tsanpo, the easterly flowing river in Tibet, which used to flow further east to pour its waters into Salween river in Burmah, got connected to Brahmaputra through Dihang, one of the north bank tributaries of

Brahmaputra. Hydrological changes brought about by this process and also by the addition of extra volume of water through Tista forced Brahmaputra to cut a new channel more or less along the Jenai and finally establishing the channel sufficiently to accommodate the additional flow. Thus, diversion took place around 1830 A.D. when another high flood was recorded in Brahmaputra. The old channel of Brahmaputra was abandoned, which still languishes along the eastern margin of the Madhupur Jungle Tract in Mymensingh district of Bangladesh. (Majumder, 1942).

Similar drastic changes also took place along the main Ganga sometimes during the early Sixteenth century. Ganga, before that, used to flow further north of its present course near the confluence of Mahananda, past Gaur, the old capital of Bengal, and used to flow along the Bhagirathi-Hooghly channel to the Bay of Bengal. The present course of Padma was established later on. Several spill channels like Jalangi, Bhairab, Mathabhanga and Gorai were thrown off from the newly established channel. Evidences are there to prove that Gaur suffered from wide spread disease of malaria when Ganga established the new course leaving behind the cut-off arm past Gaur as a vast waterlogged swamp, and the capital had to be shifted from there (Mitter Digamber, 1876). Much later, side channel erosion and accretion within the trunk channel of Ganga-Padma resulted in rapid siltation of the off-take points of the spill channels and also changing the angle of emergence of these channels from the main river so unfavourably that these channels could not draw enough water from the main river. These spill channels flowing past the vast tract of Central Bengal, being deprived of upland flow gradually lost their earlier vigour, having been left to languish on the tenuous flow from their limited catchment areas. The result was acute in deteriorating the navigability of these streams, particularly of the Bhagirathi-Hoogly channel, which was of much concern of the British rule in India. Keeping operative of the Calcutta port serving a vast hinterland and being connected to the high sea and inland areas as far as Allahabad to the west along the Ganga and

Dibrugarh to the north east along the Brahmaputra, conservancy of this river was in the highest agenda of the British rulers for obvious reasons. A number of artificial measures were taken to maintain and enhance the flow along Bhagirathi-Hooghly even at the cost of other streams of the same river system, bringing in the event more deteriorating condition of a number of streams of Central and South Bengal. To safeguard the newly laid railway lines from Calcutta towards west, through Raniganj coal fields, a number of spill channels of Damodar river, a triburary of Bhagirathi-Hooghly, were sealed off, bridges were constructed across and Grand Trunk road was protected by high embankments all along the valley. All these interfered with the natural regime of the rivers. There are plenty of records of such interventions in the river systems of India in general and of eastern India, in particular. The history of these is the history of the change of human perception and associated actions on the use of waters of the rivers. This has brought in the wake situations calling for re-look into the continuing perception, appropriateness of policies, planning and adopted technologies in this field of water resources development and demanding its proper management in the truest sense. We would like to examine these aspects starting with the present situation of eastern India within the Ganga-Brahmaputra basin in particular.

Evolution of the concept of water resources development

Of the different forms of use of water by man, irrigation consumes the largest share. In India this has been to the tune of around 87% of the total use of water, and the same, even with the claimed improved technology, has been estimated to be about 84% and 73% in 2000 and 2025 A.D. respectively. (C.W.C., 1992,1996). Except in the field of industries, increase of the use in domestic front and for live stock has been estimated at 1.3% only upto 2025 A.D., inspite of projected growth of population. Thus even in the future years, irrigation will continue to consume bulk of available waters. Obviously this situation is the result of the perception that higher agricultural production is achievable through intensification of irrigation. The same is

supported by adoption of high fertiliser and water intensive crops, which had been at the core of the Green Revolution. But the type and pattern of use of water in agriculture in India since the ancient times was much different. Choice of seasonal crops, according to climate and rainfall, harvesting of rainfall in decentralised fashion in ponds, low lying areas, resorting to flood irrigation etc. used to be the mainstay of agriculture. With these, the country was quite prosperous. Crop failures due to climatic aberrations were not uncommon, and holding this as the sole cause of famines and non-availability of food, without considering other factors in the chain of food system and society, may depict only partial truth. But in the high peak of British rule in India in the Nineteenth century emphasis was on the provision of assured irrigation to avert famine due to crop failure. In a geographical area where rainfall is concentrated in consecutive few months of a year, the rest being almost rainless, the concept of the need for conservation of water available as run-off in the rivers for use at the time it is required, originated. Voluminous waters running along the rivers to the sea were considered as resources going waste without use. The Irrigation Commission set up in 1901 favoured major works because of the idea of greater productiveness. Though not very many large works were undertaken following this recommendation, mainly on the question of probable profit return from investments, yet the logic behind the idea of maximum utilisation of river waters gained ground and the idea prevailed that "taking one year with another, the rainfall in India was sufficient for its irrigational needs, it is both possible and our duty to store the surplus of good years and to render failure of crops impossible". The technology of dams was adequately established by then as a means of creating storages of flood waters of a river. Sir Arthur Cotton, an army engineer of colonial India of the Nineteenth Century, demonstrated the means of harnessing the excess flows of the river during monsoon. He perceived that "In considering how this noble river may be improved to the utmost, it immediately occurs that our grand object must be, not to let its waters run waste into the sea. In high freshes an immense

quantity is lost because it comes down faster than it can be applied to use; in low freshes a smaller, but still very large quantity is lost at the very time that it is most required, because it is on too low a level for lands to be irrigated by it. In the first case our object is to gain time, in the second to gain height". (Lady Hope, 1964). This observation on one of the major rivers of southern India holds good for all other tropical rivers.

Indian intellectuals of science, technology and politics were drawn to this idea. This was clearly indicated in the documents of the National Planning Committee of 1938 under the Chairmanship of Pandit Jawaharlal Nehru, that "The old era, when water could be and was , used without restraint and with lavish prodigality, is coming to an end. Flood irrigation was the first or pioneer stage.... It had its origin in level surface, and superior commands obtained in alluvial tracts; the works needed were consequently not costly, as the water was taken to the extent of the low flow of the streams, and there were not many physical obstacles to overcome. There is a constant danger of scarcity of supply at critical periods and the system does not admit of high duty being obtained out of the water.... The ensuring of a fairly uniform flow of water, at the right time and place can alone make possible numerous uses of water, including irrigation. *Flood irrigation was a makeshift which has had its day,and the future development on a large scale is basically dependent upon well considered plans of storage of the high water flow of the rivers. A careful study is, therefore, needed of all opportunities for providing large scale storage reservoirs, as the handicap to agriculture can be remedied only therby"*. It further stated that "*instead of a large number of small units, we need a few strong works of large size, so as to reduce as far as possible the cost of storage and the evaporation losses consequent on exposure of bodies of water to the sun and the wind*". (Shah K. T. (ed), 1949)(emphasis added). That similar perception took deep root in Indian policy is clear from the statement of the Engineer Minister of the Government of India two decades after independence that " ..... when planning of the entire basin is taken up, the run-off of the river will not be

sufficient for all months of crop season and storage is inevitable to meet needs of deficient months ..... For using the average annual flow of the river, storage would be still greater." This has been reflected in the National Water Policy of India as "the water resources available to the country should be brought within the category of utilisable resources to the maximum possible extent. The resources should be conserved and the availability augmented by measures for maximising retention and minimising losses". (Govt. of India, Ministry of Water Resources, 1987).

Current stituations

In independent India, construction of dams for creation of large reservoirs was boosted by this perception. The situation in this domain as on to-day is that from less than 300 large dams existing at the beginning of planned development (1950-51), the number of dams constructed, including about 700 dams under construction, has gone upto about 4300. Of these, the number of completed dams within Ganga basin having live storage capacity of 10 million cubic meters (m.cu.m.) and above was 30 prior to 1950, which stood to 170 in 1989-90. Number of dams having same storage capacity under construction is 62, and some 96 are under consideration. As a consequence, the live storage capacity of the basin from completed projects rose from nearly 1.148×10^9 cu.m. in 1950-51 to 37.84×10^9 cu.m., that is an increase of about 33 times. If the volume of storage from the projects under construction is taken into account, the capacity will rise to 54.9×10^9 cu.m., or increment of nearly 48 times. Still storages of 29.59×10^9 cu.m. are projected from projects under consideration, the cumulative storage in Ganga basin in that case will stand at 84.46×10^9, or an increase of nearly 75 times compared to what existed prior to 1950 (C.W.C 1979,1990,1996, and Ministry of Irrigation, Govt. of India, 1982)

In addition to the water utilisation by storage projects, withdrawal of ground water has also been intensified during the last four decades. In Ganga basin quantity of ground water

provision for domestic, industrial and other uses is of the order of 26.03 x 10^9 cu.m., and the net draft has been of the order of 48.59 x 10^9 cu.m. (Indian Water Resources Society, 1998).

Significance of this in relation to the river regimes will be clear when the modes of utilisation described hitherto are analysed in the perspective of the resource potential of the basin.

Surface water resource of the Ganga basin, as per the latest assessment by the Central Water Commission, in the form of average annual run-off, stands at 525.02 x 10^9 cu.m. The estimated utilisable flow, excluding ground water, on the basis of the available technology, is of the order of 250 x 10^9 cu.m. Two points need be remembered, viz., (i) the bulk, more than 80% of the annual potential is generated during the four to five monsoon months only and that (ii) the projection of utilisable quantity is influenced by the topographic set-up of the basin, where, the technics being pursued can be applied only at favourable sites capable of providing space for storage. (The emphasis always being on the creation of large reservoirs). As regards the latter point, it is well known that such sites within Ganga basin may be available only in the hilly terrains in the Himalayas, or in the highlands and mountaneous regions south of the basin. After having utilised most favourable ones by now, serious constraint is imposed on this account, that is lack of further favourable sites, for storage projects. The former, that is average annual potential of the basin, assumes importance only when there exists scopes to conserve adequate quantity, the idea which lies in the core of the existing practice, particularly when almost all the storage projects are being used with multipurpose objectives. Of these, irrigation, generation of hydel power, flood control and water supply for industries etc. occupy the thrust areas. In the process of catering for these needs, the operation of reservoirs are often required to be so regulated that the river sections downstream of the dams suffer from depletion of necessary flow for maintaining the downstream regime. This is felt more acutely during the dry periods. As it is, the dry period potential of the basin is just

about 15% of average annual flow. It was observed that "in case of Ganga, the minimum flow recorded in any year in the last 30 years was about 43% of the average. The variation of daily flows is even more extreme". (Patel, 1980). Calculated on this basis, the non-monsoon potential of the entire Ganga basin within India is likely to be of the order of 79 x 10^9 cu.m. (It may be recorded that detail data on Ganga basin are not available for consumption outside the government organisations, those having been treated as classified data). The storage so far created in the basin is supposed to be by conservation of monsoon flow alone, but that sizeable quantity of the dry period flow is utilised in the projects cannot be ruled out, as is evident from the deterioration of the river channels without required flushing doses from dams.

Consequent upon the large scale abstraction of water through Jamuna and Ganga canals during the last century, it was observed that the flow, particularly during the dry season, was greatly depleted, the visible result was the reduction of navigability along the immediate downstream stretch of Ganga (Harris, 1923). Concurrently, mass scale withdrawal of ground water also adversely affects the channel flow, since during the dry weather, a river is largely replenished by the ground water. As was pointed out earlier, with reduced flow and even with normal quantity of sediments from catchment areas, the river bed gets gradually silted up, raising the bed level the result being that the enhanced monsoon flow cannot be accommodated within the channel section, and hence it overflows the banks inundating the country side. The raised bed level in the main channel often causes backflow in the tributaries, holding up their flow and causing drainage congestion and consequent flooding along the tributaries. Because of a situation where spill channels are severed from the main river, as described earlier, the flood waters of main river cannot spread out through these spill channels.

The rivers at the tail end of Ganga have suffered from other causes as well. These rivers through the alluvial terrain of delta have ideal condition of navigability when a river is in natural

state. But perturbations in the river regime were set in by natural processes long back, being aggravaicd by human actions since last century. Navigability of Bhagirathi-Hooghly was required to be maintained to keep going the port of Calcutta, which at one time served the largest hinterland and handled bulk of import and export commodities. Following the expert recommendations, the required volume of water was to be introduced into the Bhagirathi-Hooghly channel from the main Ganga. For this a barrage at Farakka was constructed to facilitate diversion of water. This action aimed at improving the navigability of Bhagirathi-Hooghly only is not free from other forms of side effects affecting not only the physical set up of the area around but engendering serious socio-political problems involving riparian regions. Besides this river a sizeable length of the navigable channels in the eastern part of India remains unattended. With growing awareness and realisation of the desirability of re-introducing transport system by inland waterways, on various considerations of cheapness, saving of fuel oil, reducing atmospheric pollution, curtailing over congestion of rail and road transport and pressure on land etc., the primary emphasis automatically rests on the proper maintenance of the river systems. Since more than one third of the navigable water length of India lies in Bihar and West Bengal, this aspect demands immediate attention in respect of river systems of these states. Each one of the factors which supports the desirability of water transport system influences not only the regional, but the national economy in a big way.

Eastern India, comprising Bihar and West Bengal within Ganga basin suffers immensely from the negative effects of water flowing through the rivers as floods. Information available for about four decades beginning 1953, indicates the following (cumulative of the states of Bihar and West Bengal, more than 82% of the geographical areas of the two states being within the Ganga basin) :

Average area affected ..... 1.9943 million hectares (m.ha) or 26.38% of the all India figure.

Average cropped area damaged ... 2.7899 m.ha., or 79% of the all India figure.

Average number of population affected ... 5.693 million, or 17.8% of all India figure.

Average value of damages to crops, houses, public utilities etc. .... Rs. 827.309 million, or 8.4% of all India figure.

It has been described earlier as to how the floods are caused in this part of India, and as to how the activities in the upper reaches have got much to contribute to the deterioration of the rivers of this part. This is borne out by the comparative current and past scenarios. In many sections of the rivers, the flood protective measures include construction of embankments parallel to the river course. These embankments, often within the river's natural flood plain restrict the lateral movement of river and hinder the deposition of silts in the natural process. As a result, the river channels become the dumping ground of river borne silts, and the bed is gradually raised. This is more acute in the tidal zone of river. In that circumstances the flood level of the river rules high, often overtopping or breaching the embankments and in the process causing more damage to the areas beyond embankments. Such flood control measures should be viewed in the light that damage is an inevitable result when man encroaches upon the flood plain, which is an integral part of the river and this is the price man has to pay for occupancy of the flood plains.

Need for and ways and means of management of river systems of eastern India

In our discussions on the management of the riverine system of eastern India, references have been deliberately made of the activities in the contiguous upstream regions of the same river basin, taking the case of Ganga as the main river. It has amply been demonstrated that a basin, transcending political boundaries is an integrated natural system, and any part of it cannot be treated separately without considering its inseparability from its watershed environment both physical

and socio-political. We have discussed at length about perception about the mode of utilising the waters of rivers, and technologies adopted towards that end. This has led to results which are not of equal interest of the riparian regions. There is something more which obviously influenced the practice by one region without considerations of the interests of others. This emanated from the Constitutional provisions. The states have been provided with Constitutional rights about the use and development of territorial waters. In the Indian Constitution water is a matter included in Entry 17 of List II, that is State List. Entry 17 of List II of Seventh Schedule of the Constitution reads as : " Water, this is to say, water supplies, irrigation and canals, drainages and embankments, water storage and water power subject to provisions of entry 56 of List I". Under this legal provision the states plan, implement and use the territorial waters largely according to their own priorities. The role of Central Government in the matter of disputes on sharing of interstate rivers has so far been proved to be peripheral. Under entry 56 of List I, the responsibility of the Central Government has been indicated. It reads "Regulation and development of inter-state rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by Parliament by law, to be expedient in the public interest". Article 262 of the Constitution authorises Parliament by law to provide for adjudication of any dispute or complaint in matters of water of inter-state rivers. Under these Constitutional provisions two Acts, viz., The River Boards Act, 1956 under Entry 56 and the other under Article 262, viz. The Inter-State Water Dispute Act, 1956 were enacted. The former could never come into operation for various reasons, and the latter has so far been used very sparingly.

Several states followed the letters of the legal provisions without following the spirit of the Union of States, that is India, which relies on co-operation and not competetion. The result was a number of inter-state water disputes, whose number became almost double between pre and post independent period (Sen Sarma, 1984).

Differences and disputes over the sharing of common rivers between two countries also put constraint against development. The case of Farakka barrage is internationally known and even with the latest agreement in 1996 between India and Bangladesh, the issue cannot be said to have been permanently settled. Unless a holistic plan is adopted for the entire basin, these problems cannot be left on the lower reach of the basin for solution or settlement, merely for housing the barrage, and which is the distribution point for sharing the Ganga waters by India and Bangladesh. (Sen Sarma, 1986). Physical effects following the commissioning of the barrage are being experienced within India in the form of large scale bank erosion, change in the river morphology of Ganga-Padma channel downstream of the barrage due to abstraction of upstream water etc. The changes in the regime may be reflected further down, giving rise to other contentious issues.

The analysis of these factors forces us to conclude that segmental use of a river without considering it in entirety is the root cause of malaises discussed so far. That planning for development of a river should be on the basis of considering it as a unit has been dawned on the Indian Planners recently and this concept has been incorporated in the National Water policy of 1987. Inspite of that the absence of proper organisation, infrastructure and planning is apparent.

The need for management (as truely an antonym of 'bungling'- Oxford & IBH, 1997) of rivers in India in general and of eastern India, in particular, because of their being integral component of the largest river of India, calls for no further justification. Each of the rivers of eastern India has its own set up and problem, and management of them is dependent on these details. We may point out some basic needs in the following form :

(1) The whole process of development of rivers demands a paradigm shift in the concept. So far the emphasis had been on considering water as a resource to be developed for its maximum use, without considering or often disregarding the health of the rivers which contain the water. Not even a fraction of the zest

and zeal with which storage projects are implemented is evident in any action for the preservation and improvement of the river channels.

(2) The development of rivers should be carried out on the basis of holistic planning for each basin and sub-basin as the unit, in the line suggested in the National Water Policy, 1987.

(3) Immediate action should be taken to create the River Basin Authorities for preparation of such plans and monitoring of their proper implementation, including the management of flood plains, which should comprise flood plain zoning with the aim of regulating activities therein.

(4) Examination and assessment of the Constitutional provisions regarding water resources development should be carried out with the objective of amending those which may otherwise give rise to inter-state differences and disputes over common rivers. For this purpose and for planning, non-conforming elements in the act of water resources development must be first rendered visible, then assimilated or eliminated in the planning process.

(5) For management of the river systems of West Bengal and adjacent areas, these can be grouped into the following categories, each of which group has different characteristics within their own larger system :

(a) Rivers of northern Bengal-mainly the tributaries of Brahmaputra. These rivers are normally flushy in nature and are fed by catchments within Himalayas.

(b) Rivers of central Bengal-mainly the spill channels of Ganga-Padma, including the Bhagirathi-Hooghly river, also known as Nadia rivers.

(c) Rivers of the coastal zone within the influence of tidal fluctuations.

(d) Rivers of the western part of Bengal, mainly the tributaries of Bhagirathi-Hooghly, from the Chotanagpur and Ranchi Plateau, including Damodar.

(6) Since any action towards improvement and management of the rivers of eastern India would involve other riparian countries, bold steps towards reaching understanding and co-operation of the co-basin countries should be taken. In the instant case of the rivers of eastern india, the existing platform of SAARC can, perhaps, be favourably utilised to create congenial atmosphere, understanding, co-operation and agreement. Joint development of the rivers of this sub-continent in co-operation with the riparian countries of the trans-boundary basins may ensure desirable management of rivers, with associated other benefits.

We are reminded of the ancient Indian wisdom and perception while discussing about the life-supporting natural water courses. "Let the water courses go on running in a well co-ordinated and well organized manner"—proclaimed Atharva Veda, and prayers epitomize the desirable approach in Taittriya Aranyakam "O flowing stream of delightful waters, may ye never run dry and look barren like an empty sky". There cannot be better logic against the existing paralogism of water resources development programmes, in support of the clarion call for immediate need for management of the same.

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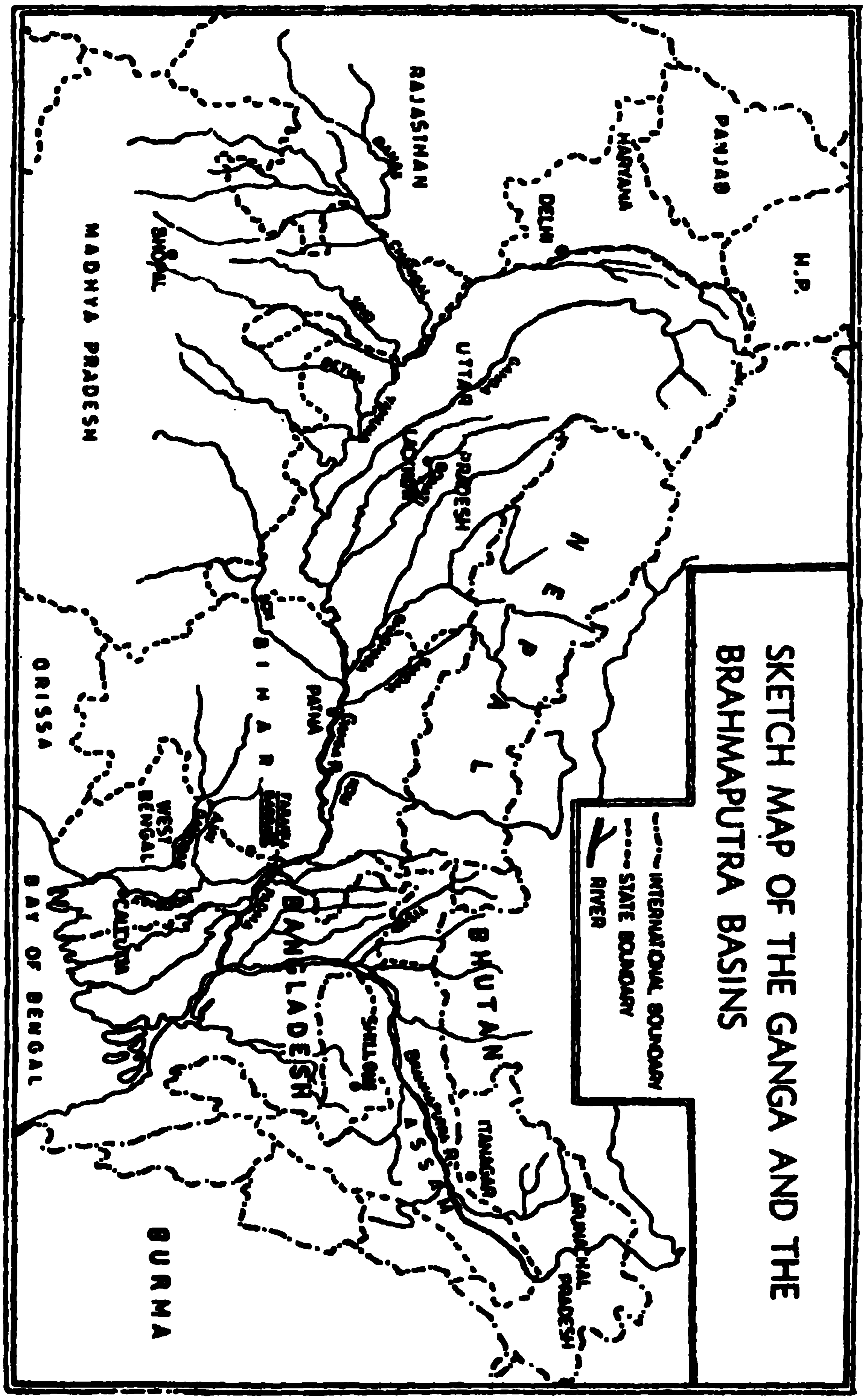
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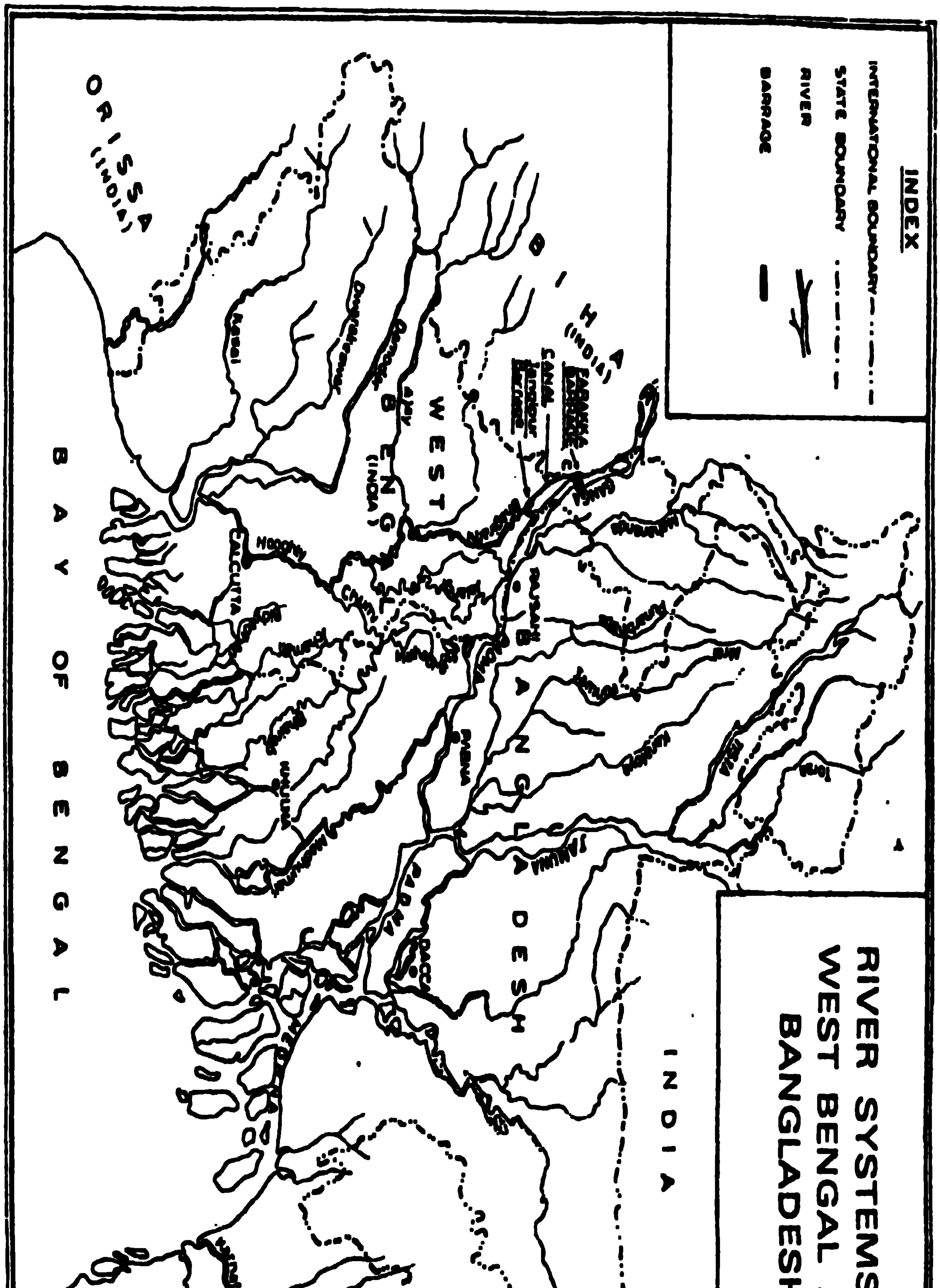
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V - 6

THE STATUS AND THE NEED FOR IMPROVEMENT OF POPULAR AND MASS BASED SCIENCE MOVEMENTS IN INDIA

SANKAR CHAKRABARTY

Popular and mass-based science movements in our country have become a part and parcel of the national mainstream today. It is also known as peoples' science movement. The word 'movement' has a specific connotation. It presupposes an objective, a goal, a directivity and above all has a positive purpose to achieve because it involves peoples' participation through awareness and initiative building exercises.

Hard Science and Soft Science

For a very long time it was difficult for the scientific community in our country to accept the very word peoples' science. Science and scientific research is purely academic in character. Its fruits might or might not benefit common man. That is purely coincidental. That was the sum and substance of their submission. They were often categorised as hard science people. Their say could not be ignored as they were the cream of our scientific community.

Those who were branded as soft science people had this to say. There is no question of diluting basic science and scientific research. But for an underdeveloped country like ours, the

directivity of scientific research has to be people-oriented. And while undertaking a technological project like building a dam, a hazardous polluting plant or a nuclear power plant, peoples' viewpoints, reservations and even resistance has to be taken into comprehension with due regards and their suggestions for any change regarding set-up, selection of site, method of construction and implementation have to be given due importance.

One must remember that at the helm of affairs of peoples' science movement in our country to-day, there are in many areas people who were at one time branded as members of hard science lobby. It is because of continuous interaction with peoples' lives and their problems that the change of heart transpired. Their contributions in various fields of basic sciences none -the-less continues.

Peoples' science

Peoples' science as a basic concept or philosophy in our country is not something which was totally unknown to us. The fruits of science and technology have to be taken to the people. The giants in our scientific world like Acharya Prafulla Chandra Ray, Satyendra Nath Bose, Meghnad Saha, Jnan Chandra Ghosh, Prasanta Chandra Mahalanabis and others had initiated us to this concept much earlier. Basic problems involving peoples' lives are so many. Which problems have to be selected for studies, investigation and research on a priority basis, that is the moot question. Here comes into question the basic viewpoint of the scientist concerned and whether he is at all aware about the field or grass-root level problems.

If the scientist or technologist and his associates resolve that they will work only on primary database collected by their own investigations involving the people and not on secondary data provided by some official department, only then a people-oriented project has any chance of success fulfilling all the aspirations ot the people.

Initiation

In Kerala, in the early part of seventies, Kerala Shastriya Sahitya Parisad or KSSP, one of the largest peoples' science organisation in India to-day undertook a programme in a classic pattern. It is known as 'Silent Valley Project' to all. It was an environmental movement which involved a very large number of people to save very rare type of flora, fauna and conserve ecological balance of Silent Valley in Kerala which was going to be threatened because of the construction of a large hydel power station in the area. It was not a movement against development as KSSP proposed to the state authorities of an alternative site for the same project.

It can be said that peoples' science movement had its initiation in India with Silent Valley movement. Another contemporary one, was the Chipko movement, whose area of operation was the Tehri-Garhwal region of the newly formed state of Uttaranchal and was meant for protection of forests from greedy encroachers. Both were environment-based movement. The pioneers of these movements again presented to us a novel technique of campaign —jathas and cultural programme which were an ensemble of song, dance and dramas. It was much easier to reach to the largest number of people through these medium rather than holding pedagogic seminars and round-table conferences, whose fall-outs are limited within a small coterie of people, though they have also their importance in their own way. The ultimate goal was to involve the largest number of people who will provide the main driving force for carrying on the movement.

One important point has to be considered from these earlier environment-based peoples' science movement exercises. People and their problems being the main issue, one has to go to the people, to the soil to have a proper grasp of the situation. Though it is an oft-repeated statement it still needs assertion as the bias on most of the occasions are on the contrary in character. It is much easier to preach, rather than to practice.

Greens

Lot of debates are going on about the role of so called green movements in our country. On some occasion their role have been found to be anti-developmental. The case of 'Sunderban Fertilisers' in Jalpaiguri district in West Bengal can be cited as one. Paschimbanga Vigyan Mancha, which happens to be the largest peoples' science organisation in India to-day took up this issue about seven years ago and could find an amicable solution as it took all sections of the concerned people into confidence, sat with them and allayed their fears. Its suggestion for a monitoring committee to look after whether the concerned fertiliser complex was endangering the local environment had a general acceptance. The ėmployment potentiality of the complex was also a major factor for consideration.

But still one has to keep in mind an important point. Every single environment-related issue or problem concerning peoples' lives have to be approached with utmost patience and forbearance rather than aggressiveness. Peoples' emotional framework of mind cannot be dispensed with carelessly.

Narmada Bachao Andolan (NBA)

A classic example in this context is the Narmada Bachao Andolan. The entire peoples' science movement of India was sharply divided on this. In the Bangalore session of All India Peoples' Science Congress in 1991, a whole night-long debate could not reach to any conclusive stand on this ussue. Some declared it as anti-developmental. Some asserted that the viewpoint of the builders meaning the engineers and the technicians have to be listened to. But when scientists with peoples' science orientation presented a graphic picture of the whole situation from their grass-root level experiences the scale almost tilted on the side of the crusaders.

We must not forget that some important technological changes as put forward by the protagonists of N.B. Andolan were given due consideration at one stage. But to achieve this a protracted and arduous movement had to be waged involving hundreds and thousands of people for a long number of years.

Due to Supreme Court's recent ruling for implementation of the dam project as planned earlier, the activists of the N. B. movement are charting out a new course of action.

In order to go into the depths and roots of a problem, it is imperative for a peoples' science organisation to be in continuous interaction with peoples' lives and their problems. It is a difficult task and demands shrugging off a lot of biased values of life.

A continuous interaction between the various voluntary and non-governmental organisations in our country are absolutely essensial for a qualitative evaluation of their performances in the peoples' science movement. Even a small group's grass-root level experiences can make a lot of important contribution. Signs of untimely aging are sometimes discernible in the three-decade old peoples' science movement of our country. This movement has aroused a lot of expectations amongst the people. Let us not dishearten them.

Mahatma Gandhi had made a prophetic statement about eighty years back —"Earth has enough resources to satisfy everyone's needs but not everyone's greed." We find an unbridled consumerism in highly industrialised countries to-day, which is depleting earth's natural resources at an alarming rate. Peoples' science movement in our country aims at industrialisation which is based on sustainable development of our natural resources and at the same time eco-friendly. We have to achieve self-reliance in science and technology but not at the cost of endangering ecological balance.

Science and technology are for the people as well as for achieving self-reliance and economic independence and sovereignty. In this age of liberalisation, globalisation and intellectual property rights, the task is getting harder. People of the country have to be kept conscious and aware about the gravity of the situation. This is also an important goal of peoples' science movement in our country.

V - 7

SCIENCE AND TECHNOLOGY POLICIES IN INDIA

SUSHIL KUMAR MUKHERJEE

Introduction

The dependence of the level of attainments in science and technology on a country's development is indeed very close. So much so that there is a continuous effort on the part of a country to upgrade its scientific and technological knowledge. It is in this context that science and technology policies of a country become a significant factor in its development.

Development is a mutifactored phenomenon. Primarily it envisages an all-round economic development, the other facets of development acting in tandem. They include health care facilities, employment generation, housing complexes, roads and transport, foodgrains, fruits, milk, eggs etc., water for domestic and industrial uses, education for all, social amenities and so on. In each of the categories of development science & technology play a crucial role. As such, institutions should be set up to create facilities for research and opportunities for enlarging the scope of improving the bases of science and technology in general.

Science is available free and is not a marketable commodity. It is pure knowledge. But technologies which are nothing but clever applications of scientific principles have commercial

values, depending on their demand and quality of performance. A scientifically equipped country is in a better position to develop technologies on its own. Or else, one can borrow technologies from those available in the world market, according to their appropriateness. The transfer of technologies from one situation to another is a common phenomenon and depends on the capability of the borrower to judge their appropriateness under the new situation. The buying of instruments, not available locally, is a common practice. But assessing the appropriateness of a technology is a more difficult task, because the factors determining appropriateness are several. For instance, if the technology is concerned with the production of a new substance, the appropriateness will be decided by the availability of raw materials, their cost, location of production site, technical assistance, etc. and finally the cost of production.

The last item, namely, the cost of production becomes the deciding factor in favour of the chosen technology. Then, there is the obsolescence of technology, the rate of which has to be taken into account in the choice of a technology. On the other hand, if a country is capable of building up technologies of its own, based on the modification or otherwise available of technologies the borrowing of technologies may be given a remote choice. Considering all these points and many more that may appear relevant, a country has to decide its policy in regard to the establishment of science and technology centres.

Science and technology policy is rather too broad. In fact, it is easy to break up initially into science policy and technology policy. This is what the common practice is. At the same time, it is more proper to merge the two and have a science and technology policy. Even then it may be important to have subpolicies, such as agricultural policy, which is itself too broad-based, and may include food policy, fertiliser policy, forest policy, land policy, price policy and a host of other various commodity policies and so on. Again, science and technology should comprehend industrial policy, education policy, Technology Development Fund, R & D Cess Act etc.

S & T Policy Studies by other Countries

Having regard to the significance of science and technology policy many developing countries started to formulate their own. In this process the scientific community of these countries as well as other developed countries have taken appreciable interest. The interest of industrially developed countries is not always without motive. The obvious factor was to sell their technologies to the newly developing countries and thereby establish a profitable commercial linkage. In fact, many such countries tried to quicken establishment of R & D centres with the help of developed countries and win the race for development in a globally competitive set-up.

During the sixties and seventies a number of scientists from the industrialised countries of Europe and America expressed their view about the policy and planning of science and technology in the emerging developing countries. These attempts were apparently to help the developing countries and to influence, in accordance with their individual perceptions, the mind of the scientists and political leaders of those countries.

A. Rahman and his co-workers have summarised these publications in their monograph : *Science Policy Studies*,[4] in the following way :

"The industrialised countries have shown considerable interest in the development of science and technology in the developing countries. This is being furthered through their aid policies. The technical assistance, more often than not, is linked with their international, political and trade objectives. The science policy studies in the industrialised countries are a part of these objectives to generate an information base for their own decision making systems and to create in general an awareness of problems of the developing countries.

The science policy studies appear to be a potent source of influencing the national policies of development and utilisation of science and technology. The impact of the studies, carried out in the industrialised countries, is quite visible on the science policy literature of the developing countries. A comparison of

the studies from both types of countries would indicate that the concepts and ideas in most of the sub-areas of studies have first appeared in the industrialised countries and afterwards found expression in the studies of the developing countries. This is evident from the fact that issues of environmental pollution, energy, R & D policies, rural development, implementation and monitoring of R & D programmes, technology forecasting and technology assessment, etc. were first raised in the industrialised countries and were subsequently taken up by the developing countries. In other words, the trend of the science policy studies in the developing countries followed the trends in the industrialised countries.

Among the industrialised countries, the United States of America and the United Kingdom have devoted maximum efforts on the science policy studies. Asian countries received main attention. Considerable number of studies have been published on China and India. It may be seen that the trend is now gradually shifting towards African and Latin American countries.

During the seventeen years (1960-1976) the highest contribution has been made in the area 'science and technology policy making'. The remaining areas 'plans, programmes and projects related to scientific and technological activities', 'science and technology resources, and foundations of science and technology', shared rest of the publications in descending order. Major efforts were devoted to the sub-areas, namely, implementation and monitoring of science and technology policy, technology assessment, human resources, economics of science and technology, R & D policies for agriculture, energy and industry and socio-economic and cultural research. On the basis of the on-going research projects, it may be said that interest is now concentrating on technology transfer, appropriate technologies and sectoral R & D policies.

Teaching of science policy studies is also an emerging trend in universities and colleges. In future, more institutions are expected to initiate the study of the developing countries as part of the teaching programmes on 'science, technology and public policy'.

A consistent output of studies was noticed in the sub-area of international co-operation in science and technology. It continues to get, more or less, the same emphasis in the on-going research efforts. It is also acquiring a respectable position in the teaching programmes.

For the purpose of studying the character and the salient features of the studies, the period under review has been categorised into three phases. The first phase, the period upto 1962, was highly favourable to the industrialised countries in relation to international trade with the developed countries. In matter of technology export what was offered to the developing countries was acceptable to them. This has precluded any need of a serious study of the science policies of the developing countries by the industrialised countries. In the second phase, between 1963 and mid-sixties the national policies in the developing countries were concerned with technological gaps. This consciousness was matched with increased number of studies on transfer of technology from industrialised countries to developed countries. During the third phase, between late sixties and the seventies the Western technological model was criticised the world over. The developing countries came to realise that the new technological order must at least meet the basic minimum needs of their people. Under these circumstances the industrialised countries responded with a spate of studies suggesting the development of intermediate and appropriate technologies for the developing countries.

The studies published by UN agencies are the primary sources, information and data on the developing countries, which otherwise are not easily available. They cover only a limited number of sub-areas of science policy studies and are thematically similar to the studies of the industrialised countries. However, they do not reflect any critical analysis of the national science and technology policies."

Also included in the above study is a list of references appended by the authors. The references with regard to India have been ticked. It will be seen that the papers by PMS Blackett in general and of Morehouse on India in particular are of great

interest. Both of them played a key role by exercising their influence on the then scientists and politicians of India.

Government Involvement in the Promotion of Science & Technology

A notable feature since Independence has been the increasing involvement of the government in the promotion of science and technology in all aspects. In addition, government and the various research agencies have developed collaborative programmes, bilateral agreements, exchange of scientists with other countries including the USSR, USA, France, West Germany, Yugoslavia, Australia etc. In addition, Indian scientists participate in the programmes of UNESCO, World Health Organization, International Atomic Energy Agency and other international bodies. India has entered into co-operation agreements with over 25 countries, covering various aspects of scientific research and technological collaboration.

Three decades ago Jawaharlal Nehru expressed his optimism in the following words : "Tomorrow's India will be what we make it by today's labour. I have no doubt that India will prosper industrially and otherwise, that she will advance in Science and Technology; that our peoples' stars will rise, that education will spread and that health conditions will be better and that art and culture will enrich peoples' lives. We have started on this pilgrimage with strong purpose and good health and we shall reach the end of the journey however long that might be". His hopes have been realised only to a limited extent. The tasks ahead are indeed gigantic. What seems to be baffling is the mechanism of transfer of technologies to the rural areas where about 75% of the population lives. But still more baffling is the question whether these technologies are at all applicable for development of rural areas. They were generated primarily to satisfy urban needs, without caring for the differences between these and rural needs. Scientists themselves are unfortunately not aware of rural needs. Moreover, the scientific community in India seems to be circumscribed by social and political forces of chauvinism, religious bigotry, caste considerations and fissiparous tendencies, which have resulted in a type of a

negative feed-back on the delivery mechanism. The scientific community itself, not unoften, appears to be beset with personal and hierarchical problems, reflecting similar situations obtaining around them in other fields. The scientific temper, as Nehru wished, has to permeate all kinds of political, educational and social institutions and even individuals. Only then would science and technology be able to play an effective role in national development.

The decade preceding independence, with the intervention of the Second World War, saw science, scientific organisations and training applied to meet specific needs of temporal nature. Planned efforts were lacking in any venture whatsoever. Even then some sort of scientific development was registered. There were, for instance, during this period some twenty universities, 500 arts and science colleges and 140 colleges of professional and technical education. Eight universities offered postgraduate courses in different branches of science and 38 engineering institutions were imparting training to nearly 3000 students annually. The total number of scientific societies was around 60 : 9 for physical sciences, 11 for medical sciences, 14 for biological sciences including agriculture, 15 for engineering and technology and 10 of general nature. The average annual turnover of postgraduate science students was over 900, and of the engineering graduates, over 1000. By 1947, there were nine Fellows of the Royal Society of London one of them being a Nobel Laureate.

The alien government had set up the Industrial Commission (1916-18) to enquire into the industrial profile and the technical manpower needs of the country and Royal Commission on Agriculture (1927) to examine the agricultural problems. Their recommendations, albeit their limitations, resulted in some new thrusts in the respective fields. The establishment of the Imperial Council of Agricultural Research was one of the recommendations of the Royal Commission on Agriculture.

Principally, apart from the scientific/survey organizations, there were agencies like The Indian Research Fund Association (1911) which later developed into the Indian Council for

Medical Research; the Imperial Council of Agricultural Research (1929) and the Board of Scientific and Industrial Research (1940), the forerunner of the Council of Scientific and Industrial Research (1942) which was established to organize research programmes to meet the demands of the then war situation. In the last decade before Independence the Indian National Congress set up a National Planning Committee (1939) of which there was a sub-committee for science and technology. The moving spirit behind the concept of planning for development, the paramount role in it of science and its applications, was Pandit Jawaharlal Nehru, the architect of modern India since Independence.

Nehru in his *Discovery of India*, expressed his conviction in these words : 'it was science alone that could solve the problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening custom and tradition, of vast resources running to waste, of a rich country inhabited by starving people.' To him science was the most effective and purposeful pursuit and its applications alone would usher in social transformation and ward off inequities of various dimensions which afflict mankind. His pensive mind had a wider perspective of science, viz., its method and its national character, the scientific attitude or the scientific temper as he used to refer to it. To Jawaharlal Nehru, more than any other, India is indebted to the firm foundation laid by him, soon after Independence for the multilevel growth of science and technology.

Nehru had the essential attributes of a real man of science in the larger laboratory of life. He exhorted time and again that a dispassionate scientific temper would be of great value in solving problems in every walk of life, even in the Parliament, although he was well aware of the destructive dimensions of science. Throughout his nearly seventeen years of stewardship of the nation, Nehru was intimately associated with the scientific community, and the scientific organisations, lending his prestigious personality to the development of science in India, as an integral component of the successive Five Year Plans. In the words of Nehru, "Planning is science in action, and the scientific method means planning.'

In March 1958, he moved in the Parliament the Scientific Policy Resolution. The aims of this policy were, among others, 'to foster, promote and sustain, by all appropriate means, the cultivation of science and scientific research in all its aspects, pure, applied and educational; to ensure an adequate supply, within the country, of research scientists of highest quality, and to recognize their work as an important component of the strength of the nation; to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity; to encourage individual initiative for the acquisition and dissemination of knowledge and for the discovery of new knowledge, in an atmosphere of academic freedom; and in general, to secure for the people of the country all the benefits that can accrue from the acquistion and application of scientific knowledge as also to offer 'good conditions of service to scientists and accord them an honoured position by associating scientists with the formulation of policies.'

Soon after he became the Priime Minister of India, Nehru created a ministry of scientific research and natural resources, and actively supported the atomic energy programme for peaceful purposes. In 1948, the Atomic Enegv Act was passed and the Department of Atomic Energy was directly under his charge.

The First Five Year Plan emphasized the role of science thus : 'In the planned economy of a country, science must necessarily play a specially important role. Improvements in techniques evolved as a result of scientific research bring about great increases in production in the different sectors of the economy. A balanced programme of research covering every sector of the economy is, therefore, essential for the development of a country'. Over the successive Five Year Plans, the role of research and development activities has received enormous support from the government.

In the Scientific Policy Resolution (SPR) as passed by the Parliament in 1958, no mention has been made about the need of such a resolution. Also surprising was the fact that no mention was made in the preamble of the scientific organisations and

institutions such as the Atomic Energy Commission, the setting up of the National Physical Laboratory, National Chemical Laboratory, Central Fuel Research Institute etc., which came up before the SPR, and how they fit in with the policy statement made in the SPR. It may be noted here that Directors of the above organisations were initially British or American scientists. One is curious to know how these steps were in agreement with the policy laid down, though very briefly, in the SPR.

Even before the adoption of the SPR, Nehru had set up an Advisory Committee for coordinating various scientific activities under his chairmanship and the Scientific Advisory Committee to the Cabinet (SACC) under the chairmanship of H. J. Bhabha (1956) to advise the cabinet on the formulation and implementation of the Government's science policy and on the scientific and technical cooperation with other countries. The membership of the Committee included the Cahinet Secretary and heads of scientific agencies. One may easily find out that these steps taken by the Govt. have nothing to do with the SPR. In fact, there is no specific guideline for such steps in the SPR. SPR, it seems was thus merely ornamental in nature. Not only so, the SPR as mentioned earlier did not at all refer to the National Planning Committee (1939) set up under the chairmanship of Nehru by the Indian National Congrèss, even though this Committee had a subcommittee on science and technology, with M. N. Saha, S. S. Bhatnagar and J. C. Ghosh, J. N. Mukherjee as members.

In fact, in the further steps taken in the formulation of science and technology policies, the SPR played no role whatsoever. In that sense SPR stands isolated and hardly referred to by any science and technology establishments.

SACC under the chairmanship of Bhabha worked till 1966 when he met a tragic death. In 1968, SACC was found to be inadequate for coping with the expanding horizon of S & T and gearing its deliberations to the social and economic policies of the Government. It was replaced by the Committee on Science and Technology (COST) with wider terms of reference and a broader composition of its members under the chairmanship of

a Member of the Planning Commission. The COST was expected to advise the Government on science policy, determination of national priorities in scientific research, monitoring the pace of development of scientific research with a view to correcting imbalances, if any, coordination, utilization of the nation's scientific and technological resources and consistent with the needs of national development, the proper balance between the indigenous efforts and import of foreign technology, co-operation with international scientific organizations etc. In its short life span of just three years, COST attempted to bring out a status report and a review of the implementation of the Scientific Policy Resolution but with limited success.

To meet the newer urges and aspirations of the scientific community and of the nation itself, the Government, in lieu of COST, set up the National Committee on Science and Technology (NCST) in November 1971. the functions of the new Committee included "the preparation, evaluation and updating of a national science plan — both five year and perspective plans, in close cooperation with the Planning Commission, especially in the context of the relative priorities and allocation of resources; the pattern and mode of development of S & T and manpower; attainment of self-reliance in S & T through the full utilization of the nation's scientific and industrial resources; coordination among different agencies and sectors; international cooperation mechanism etc."

The Chairman of NCST was the Minister for Industrial Development, who was also the Vice-Chairman of the CSIR. In January 1975, the NCST was reconstituted, this time with the Deputy Chairman of the Planning Commission itself as its head, in order to bring about a greater degree of coherence between the socio-economic plans and those of S & T.

Science and Technology Plan

In the scientific progress of the country, a significant step was taken by the NCST to prepare, for the first time, a comprehensive S & T Plan (1974-79). The NCST prepared an Approach to S & T Plan in 1973, subsequently the S & T Plan.

It adopted a combination of 'a sectoral approach and an overview of the totality of the nation's scientific and technological needs'. The plan was examined in 24 sectors, studying each sector critically with a view to evolving suitable programmes of research, development and design (RDD) for accomplishing the time-bound targets. It may be noted that the S & T Plan prepared by the NCST was not without limitations in as much as the agencies concerned with agriculture, atomic energy, space and electronics had to work out their own plan targets. Yet a notable aspect of the S & T Plan was the purposeful dialogue among scientists and technologists from various organizations on the one hand, and economists, administrators and other professional groups on the other. The RDD projects presented in the S & T Plan include import substitution, adaptation of imported technology, enhancement of industrial productivity, export promotion, building up capabilities in frontier areas and augmentation of R & D.

Technology Policy

The S & T Plan was not so long backed by an appropriate Technology Policy Resolution. However, the Government of India has thought it necessary to enunciate the Technology Policy Statement (1983). It is based on the address by Indira Gandhi at the 1983 Indian Science Congress session. The main aims of this policy are : To attain technological competence and self-reliance, to reduce vulnerability, particularly in strategic and critical areas, making the maximum use of indigenous resources; to provide the maximum gainful and satisfying employment of women and weaker sections of society; to use traditional skill and capabilities, making them commercially competitive; to develop technologies which are internationally competitive and have export potential; reduce demands on energy, specially from non-renewable sources; ensure harmony with the environment, preserve ecological balance and improve the quality of the habitat; and recycle waste material and make full utilization of by-products. The overall emphasis will be on food, health, housing, energy and industry. The import of technology and foreign investment will continue to be on a selective basis.

Efforts will be supported for the adaptation and subsequent development of the imported know-how through indigenous R & D.

A new Technology Policy formulated by the DST was adopted by the Parliament in 1993, ten years after the first Technology Policy Statement was formulated. The new Technology Policy refers marginally to the 1983 statement, the SPR (1958) and the Industrial Policy (1991). The new Policy is designed to further strengthen the Indian economy and to assist the nation in fulfilling its role in the global economic environment with confidence and a sense of urgency. Even though not stated categorically, it was the globalisation and liberalisation of economy that prompted the new Technology Policy (1993).

The new policy in its preamble ought to have outlined the part played by TPS (1983), the extent of its implementation, its inadequacy in taking care of the new situations arising in the economic and political firmament of the country. This important part of the introduction to the new TP was conspicuous by its absence. The new TP did not also take notice of the steering group on S & T for the formulation of the 8th Five Year Plan. It is strongly felt that instead of a new TP a new S & T policy was in order at this stage of our S & T organisation when there are more than 300 S & T institutions and 900 in-house R & D laboratories of varying capabilities in the public and private sectors.

Such important items as Indigenous Technology, Technology Transfer, Technology Impact Assessment, Technology Absorption, Adaptation and Innovation, new Technologies appropriate to time and space find scant mention in the new TP but were reasonably elaborated in the 1983 TP. The deficiency is noteworthy, but no explanation has been given.

The new TP has failed to take notice of the contributions of CSIR and IITs in the area of Research, Development and Engineering. There ought to have been suggestions to modify the mandates of these organisations in order to be of greater and better use. In recent years, biotechnology which involves

genetic engineering, immobilised biocatalytic systems, cultivation of animal, plant and microbial cells, fusion of unrelated cells and cultivation of the resulting hybrid, enzyme engineering and systems engineering is opening up new vistas in the fields of agriculture, forestry, health care and specific diagnostic reagents, process kinetics, fermentation reactor design and the like having possibilities of far-reaching economic and social significance. In order to keep pace with this fast emerging area and to provide policy and financial support, a National Biotechnology Board has been set up. Both short and long term plans have been under way in respect of institutional facilities and infrastructure, manpower development, R & D programmes, their priorities and coordination, Even before the formation of the Board, certain institutions and individual scientists have been engaged in some of the areas of Biotechnology. Workshops and seminars have beeen organized, for instance, in immunology, bioengineering, recombinant DNA techniques, tissue culture etc. The National Biotechnology Board has formulated integrated training programmes in molecular biology, genetic engineering and microbial genetics etc., to develop manpower and technical skills.

The Science Advisory Council to the Prime Minister (SAC-PM) was constituted in 1986 as an apex body to advise the Prime Minister on major issues related to S & T in the country and also to prepare a perspective S & T plan for 2001 AD. The Council was also expected to examine certain matters concerned with the scientific departments, priorities in research and development, technology missions and so on. The technical reports finally prepared by the Council are now available in two volumes of Perspectives in Science and Technology. The first volume contains (a) the approach paper prepared by SAC-PM on perspective science and technology plan for the year 2001, and (b) seven other reports on the frontier areas of research and development. The second volume contains nine more reports broadly classified under the category of 'areas of socio-economic relevance'.

Technology Missions

Technology Missions programmes launched between 1985 and 1989 are meant to speed up development. They focus on certain key human needs and have been categorised under seven heads :

(a) *rural drinking water*

(b) *immunisation of infants and pregnant women*

(c) *adult literacy*

(d) *self-sufficiency in edible oils*

(e) *improving the telecommunication network*

(f) *dairy development*

(g) *wasteland development.*

The annexe gives an account of how the programmes are to be implemented, the part to be played by the Centre and the States and the achievements made so far.

The document on the 1983 Technology Policy Statement emphasised that self-reliance is the pivot of technology development and technology assessment. Surprisingly, in the Technology Policy Statement (1993), which was hurriedly passed by the Parliament, the concept of self-reliance was conspicuous by its absence. It heralded the advent of globalisation and market economy. It did not even care to explain why the spirit of self-reliance was not our first concern. Indeed, it was our first concern to set up big industries and boost up economy. The industries were based exclusively on borrowed technology. Thus, we sacrificed knowingly self-reliance in order to industrialise quickly. We paid little attention to what the consequences of such steps could be. In fact, we did not lay down any policy regarding the applications of S and T that would create a climate of well being of the people at large and generate employment. The hazardous consequences of such a step, namely, industrialisation at all cost, must have prompted the author of the TPS 1983 to emphasise the usefulness of self-reliance in promoting industrial development.

A critical study of SPR and the two TPS's reveals that what is wanted is an S & T policy, instead of separate S and T policies.

There is another dimension to the joint S & T policy in view of the fact that usch a policy cannot afford to ignore the social implications of S & T in general and of societal developments in particular based on the joint S & T policy.

Moreover, the S & T policy should be of such depth and so extended that sectoral policies like industrial policy, energy policy, education policy, manpower policy, water policy, agricultural policy, economic policy etc. emanating from the main S & T policy, find their proper places. Unless the interdependence of all these different policies is clearly understood and delineated, it may be impossible to work out comprehensive programmes of development in a balanced manner.

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V - 8

A CRITICAL ASSESSMENT OF THE SCIENCE & TECHNOLOGY POLICY OF INDIA AND ITS IMPLEMENTATION

ASHOKE MUKHOPADHYAY

It is a great pleasure and privilege for me to be invited to deliver a talk before such an august audience on the Science and Technology Policy and its Implementation in India. Since this is a part of a larger course of deliberations on the history of *S & T* in the Indian perspective in which many distinguished scholars take the floor to enlighten you, I am not sure how far and whether at all my discussion will fit into the general scheme of the course. Although a science activist and writer, I am not a scholar in any sense of the term. My rights in expressing some critical remarks on the *S & T* Policy veer round the position of an active, conscious, responsive and responsible citizen who has some definite expectations from the *S & T* regime as well as some clearly communicable experience.

In preparing myself for this talk within the given span of time the greatest difficulty was to find out suitable literature. Even the official documents are not easily available, not to speak of the evaluations made by different people. What I shall attempt here is to describe a legible picture of the *S & T* regime in its socio-historical context in India. The discussion, although comprehensive, is, therefore, far from exhaustive. I will consider

my labours to have been productive if this discussion inspires any body to continue the assessment more thoroughly, in greater detail, gathering larger volume of facts, figures and opinions.

Prelude to the Policy

Modern Science in India started as a social movement, as a part of the total national awakening in the late 19th century. Even the earliest generations of science graduates like J. C. Bose had embarked on research as soon as they joined the science teaching profession. The first research institute of the country was also established long back in 1876 almost as soon as science education was introduced at the then existing universities. And it was this institute which had housed the work of the only Nobel awarded scientist of India till now. In view of such facts it can be justifiably claimed that *S & T* researches in India had been long ahead when the *S & T* policy was adopted in 1958 by the Indian Parliament under the active stewardship of Jawaharlal Nehru.

History being written more by the surviving rulers than the history makers themselves, actual roles are always understated or exaggerated. Nehru has been wrongly overcredited with the launching of a grand *S & T* promotion policy. Historically and factually it was taken at the 1938 session of the Indian National Congress under the presidency of Subhas Chandra Bose. In his presidential address he had said : "Though it may be somewhat premature to give a detailed plan of reconstruction, we might as well consider some of the principles according to which our future social reconstruction should take place. I have no doubt in my mind that our chief national problems relating to the eradication of poverty, illiteracy and disease and to scientific production and distribution can be effectively tackled only along socialistic lines. The very first thing which our future national government will have to do would be to set up a commission for drawing up a comprehensive plan of reconstruction."[1]

In a meeting with the Indian Science News Association then

conducted by Professor Meghnad Saha, he spelt out that "national reconstruction will be possible only with the aid of science and our scientists"[2]. There he also spoke of organising proper scientific and technical education and about forming a "permanent National Research Council". Finally, he appealed to the scientists : "We, who are practical politicians, need your help, who are scientists, in the shape of ideas. We can, in our turn, help to propagate these ideas and when the citadel of power is finally captured, can help to translate these ideas into reality. What is wanted is far-reaching co-operation between science and politics."[3]

Thus it is to be recognised as a fact that Bose as the President of the Congress was the first and the only official spokesman before independence, to have highlighted the importance of *S & T* in the national reconstruction work of independent India. Nehru, on the other hand, although much more inclined towards adopting the modern way of life in his personal opinion, was too careful to propagate these ideas from the official pulpit, perhaps with an eye to Gandhi's reaction thereabout. Moreover, it is also a noteworthy fact that Nehru required eleven years to formulate the *S & T* policy after assuming office and not during the first Five-Year Plan.

The Policy of 1958

Modern science and technology developed in the European countries without any official policy pronunciations. But in India a policy was required for two precise reasons : (a) to overcome the obstacles imposed by colonial rule in a sweepshot; (b) to shatter the more formidable obstacles of the ageold religious orthodoxy. Naturally, India after independence required a *S & T* policy of the Union Government which would take cognizance of these two sets of obstacles and declare an official pledge to remove them with all the earnestness and force the task demanded.

But when one looks at the *S & T* policy of 1958, one is taken aback. It was only the first set of obstacles which was considered and targetted. The policy was eloquently silent on the question

of the second set of problems.

As a result, it contained some highly euphoric phrases about the contributions science and technology could offer to the nation. It declared the following as the aims of the policy :

"(i) to foster, promote and sustain, by all appropriate means, the cultivation of science, and scientific research in all its aspects — pure, applied, and educational;

"(ii) to ensure an adequate supply, within the country, of research scientist of the highest quality, and to recognize their work as an important component of the strength of the nation;

"(iii) to encourage, and initiate, with all possible speed, programmes for the training of scientific and technical personnel, on a scale adequate to fulfil the country's needs in science and education, agriculture and industry and defence;

"(iv) to ensure that the creative talent of men and women is encouraged and finds full scope in scientific activity;

"(v) to encourage individual initiative for the acquisition and dissemination of knowledge, and for the discovery of new knowledge, in an atmosphere of academic freedom;

"(vi) and, in general, to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge."[4]

It was, as it were, implicitly assumed that given a policy encouragement to science and technology, scientific and technological knowledge and research would take off automatically, and that the benefits would be available to the people in general. The main task of the government was supposed to be to apportion money for establishment of *S & T* institutions, researh institutions, relevant departments in the universities, appointment of personnel, publication of journals, so on and so forth.

In themselves these were very important. But these were not enough, nor the primary requirements. The primary requirements were to create the rational intellectual atmosphere within the country in general and the academic institutions in particular which could be congenial to the pursuit and propagation of scientific knowledge. That was left undone. That remains so even today.

Achievements : 1958-1998

Of course, as a consequence of independence and also of the *S & T* policy, the growth of science teaching and research institutions as well as *S & T* manpower was quite impressive. Whereas on the eve of independence, the country had only 18 universities, today that number stands at around 210. Of course, this includes 5 IIT's, 5 ISI's, the IISc and other deemed universities or degree-awarding institutions. Today there are more than 7500 colleges of which 6400 offer science courses of varying levels, 500 in engineering, 450 in medicine and 150 in agriculture. Besides, there are nearly 900 polytechnic institutes all over the country.[5]

In the year 1992-93, the annual enrolment in the science and technology disciplines was about 1.4 million, the annual output of *S & T* graduates was about 200,000 and total number of *S & T* personnel was nearly 4 million.[6]

During the last 10 years, the budgetary allocation for *S & T* has also shown remarkable nominal growth from Rs. 1155 crores (1989-1990) to Rs. 4261 crores (1998-99) and somewhat proportional increase, from 1.24 per cent of the national budget to 1.59 per cent by the same period.[7]

Naturally, as a result of this infrastructural development *S & T* teaching and research gradually received momentum, diversified into ever newer branches and areas and led to some tangible results in the development of a well-equipped group of experts in various fields.

The expertise has been reflected in three major areas : (a) agriculture, (b) space , (c) nuclear reactor. Indian scientists

have successfully copied and transplanted high yielding variety seeds of wheat and rice in Indian soil thereby raising food production and making India virtually self-sufficient in these two major crops. (The cost-benefit analysis of this euphorically-called "green revolution" is yet to be made with respect to the long-term ecological disequilibrium and pollution caused thereby.)

In the high-tech area of space research, Indian scientists have successfully launched a polar satellite launch vehicle (PSLV) and by placing the IRS-P2 satellite into orbit has joined the select group of countries capable of launching 1000 kg class satellites into polar sun-synchronous orbit. India is now self-sufficient in this area of designing, building and launching its own satellites and missiles.[8] It has acquired a quite considerable missile power for military purpose.

India has achieved something in the management of nuclear reactors. While generation of electricity from the nuclear power station is quite poor (but that is in all countries), it has been possible for India to use them for manufacturing nuclear weapons — of both fission and fusion type.

Besides these, Indian computer scientists have developed some indigenous super-computers, most notable among which is PARAM 9000 with a capacity of 2.5 gigaflop. Indian scientists have been able to crystallise one of the best known natural products of neem, Azadirachtin-A, which possesses amazing attributes including the ability to act as an anti-feedant to more than 200 species of insects. India, for the first time, filed a patent for genetically engineered gene from the mature seeds of the amaranth, a pseudo-cereal with a rich protein content; this gene can be introduced into other cereals to increase their protein content. A considerable number of technologies have been developed and commercialised in the area of petrochemicals, agrochemicals, industrial catalysts, food processing, drugs and pharmaceuticals, engineering materials and equipment, construction materials, etc. Many of these are also marketed abroad.[9]

Another indicator of the growth of scientific and technological information is the number of patents filed in a year. The following table gives a good overview of the picture [10] :

Patent Application	
Year :	No. of Patent Application
1990-91	1180
1991-92	1293
1992-93	1228
1993-94	1266
1994-95	1741
1995-96	1606
1996-97	1661

It is also a well known fact that Indian technologists are invited abroad in many of the developing countries in Asia and Africa as experts and consultants in electrical or railway construction works, etc.

These facts can be cited as proof of the success achieved by the *S & T* policy in India.

Failures

Now, when one looks at these facts, impressive as they are, and probes into a bit more detail, one is struck by another bare-toothed truth. Almost all these achievements are in the field of technology and engineering — in the application of available scientific knowledge. But where are the cases of generation of new scientific knowledge?

It was officially acknowledged in 1987 that "when viewed in the context of the pace of development in Science and Technology in other parts of the world, the nature and dimensions of the problems of national development confronting us and the immense potential of *S & T* to help solve current problems, it is found that, despite significant advances, the gap between India and other advanced countries has significantly widened in terms of scientific and technological capabilities."[11]

It may be worthwhile to extract some comments from an article in the popular science journal — "Science Reporter". The author, a teacher in the department of Physics & Astrophysics of Delhi University, curtly observed : "What is the state of science in India? With the second largest trained scientific human resources in the world, a large network of scientific laboratories and universities, is there anything really wrong with science in India? Or is science flourishing in our country?

"Looking at any of the indicators of quality, it is evident that though the "quantity of science" practised in the country may be impressive, we are still way behind in coming upto international standards in the *quality* of science. Whether it is the citation index, or international awards or publications in peer-reviewed journals, our scientific output leaves much to be desired as far as quality is concerned. .... On the golden jubilee of Indian independence we can boast of many achievements in science and technolgy .... A nation with a sixth of the world's population cannot even boast of a single Nobel Prize in the sciences since independence, or claim to have invented any technology of global impact."[12]

The point is well made. Success of a policy is best judged by the results. While the 1958 policy may be considered successful in creating a well-established framework of modern science and technology in respect of teaching and application, it was hardly able to create the background where the infrastructural facilities available would make major breakthrough in *S & T* research possible. Thus something seems to be very seriously wrong with our scientific establishment.

It might be argued — and also with reference to the science policy —that Indian science paid greater or exclusive attention to the problems of national construction at hand, "to secure for the people of the country all the benefits that can accrue from the acquisition and application of scientific knowledge". But, as the D.U. teacher points out, "science as practised in our country has not even touched the lives of the vast majority of

our population. Whether it is the basic design of the bullock cart wheel which has been unchanged for centuries or even the bicycle, our scientific establishment has proved, except a few notable exceptions, to be incapable of any innovation which touched the lives of our people."[13]

For example, it was officially noted that despite having a vast and ever increasing network of bus-transport in this country, "both chassis and bodies continue to be built with age-old and outdated technologies" without "improving riding comfort and reducing fuel consumption". It further pointed out : "We are the largest producer of bicycles, fans and sewing machines in the world and yet no R & D inputs have gone in these areas. We are the largest producers of sugar, but again our technology remains old and outdated."[14]

Thus our entire scientific and technological edifice has been much more efficient to absorb and apply the knowledge generated elsewhere in the world than to add any significant part to such knowledge.

On the other hand, the very facts that flood and drought could not be controlled, rivers were gradually led to lose çarrying capacity and to dry, safe drinking water could not be provided to a larger section of the population, child mortality, general malnutrition, and incidence of malaria, gastroenteritis, tuberculosis, etc. could not be reduced, the general and medical scientists could not timely respond to the problems of arsenic pollution in West Bengal, etc. etc., glaringly point to the failure of the science policy to achieve any of its declared objectives over the decades.

Ultimately, in the year 1988, the Science Advisory Council to the Prime Minister, in an approach paper, was constrained to note that "it has become clear to the Council from its discussions with the Planning Commission and the Economic Advisory Council that planning for our science and technology is not yet integrated with planning for economic development."[15] Put more explicitly, it could be stated that *S & T* has not become and is

not made the guiding force of our socio-economic development. And to correct the situation the Department of Science & Technology brought out in 1993 a "Draft Paper for a New Technology Policy", which was, however, not tabled for adoption in the Parliament during the last six years. The failure to draft and adopt a new *S & T* Policy Resolution in the present context crowned the failures with respect to fulfilment of the 1958 policy objectives.

Ideological Constraints

The cogent question is, why? What is wrong with the *S & T* Policy? What are the reasons for the non-implementation of its directives?

In my opinion, the answers to such questions can be found only if we probe into the socio-cultural context of the country in which science and technology policy was developed and to which it remained indifferent.

There is no two opinions about the fact that the cultural and political movements of pre-independence India were heavily tinged with religious colour. The mainstream of the national movement was successful in uniting the Indian nation at large on the question of political independence but utterly failed to achieve the cultural-emotional integration of the people on questions of religion, caste, language, etc. While it was necessary to mobilise and organise the people with appeals cutting across these horizontal particularities, the remnants of feudal culture, and thereby to democratise and secularise Indian society and polity, the dominant leadership represented by Gandhi chose to appeal to the religious sentiments of the people. This wrong principle, instead of achieving its intended goal, national unity, actually resulted in three parallel movements splintering from the national movement, namely, the Muslim League separatism, the RSS-Mahasabha Brahminical chauvinism and the Ambedkar-inspired Scheduled Caste and Tribes social upliftment movement. The end results are too wellknown to need be recounted here.

But what is relevent here is to enumerate the consequences of religious and caste feelings with respect to the rapid development of a scientific culture in a country like ours.

The prevalence of religious orthodoxy in a society trammels the thinking process within the narrow bounds of the inherited and conventional wisdom, discourages any major and serious departure therefrom and thereby obstruct the very rational and creative spirit essential for original research. In the countries of Europe these intellectual fetters were shattered by a series of warfares between the Christian orthodoxy and the emerging scientific spirit, through the democratic revolution against feudal monarchy and aristocracy and in course of the establishment of secular states and secular education system.

In India, the secular voice among the reformers, cultural and literary stalwarts as well as political leaders was very feeble. Except few personalities like Vidyasagar, Sarat Chandra, Premchand and Bhagat Singh, most of them were influenced by the revivalist ideological currents created by Ramakrishna-Vivekananda-Bankim Chandra in Bengal, Dayananda-Shraddhananda in Northern India, and so on. This revivalist movement was able, thanks to our mainstream national leadership, to create a strong nostalgia for a "golden past" in ancient India. It highlighted a system of philosophy as the highest epitome of ancient Indian wisdom - namely Sankar's Advaita Vedanta —which actually had discouraged any pursuit of knowledge. It overshadowed all the material and substantial knowledge really acquired in ancient India. A large number of Indian science and technology literates also shared (and still share) the belief that all achievements of modern science go to vindicate the standpoints of Vedanta philosophy.

In view of this intellectual climate it was necessary for the Indian state to pursue a strictly secular policy in all its public affairs and to introduce a truly secular education —in order to create and process the raw materials of the *S & T* manpower. However, neither the Indian state was declared "secular" in the Indian Constitution after so much of prolonged exercises in the

Constituent Assembly, nor was the education made truly secular. While in all the private and public sector industrial units Viswakarma Puja is being held by their employees, similarly Saraswati Puja is organised in all educational institutions, by the students and teachers, with much fanfare. Most of the holidays are centred on the religious occasions. The history and literature course books in the school level contain elements of religious, mythological and communal beliefs in varying degrees. Two central universities, maintained by government support bear the epithets "Hindu" and "Muslim" in modern India. The Science Policy of 1958 made no attempt to reverse this process and thereby, to reshape the raw materials of the *S & T* manpower. The educated literati who join the *S & T* research hardly ever imbibe the spirit of M. N. Saha or P. C. Ray but start their work with an already trammelled outlook.

Secondly, owing to the prevalence of casteism, the upper caste people who come to the *S & T* research most often abhor the manual work to be done centring round their tools, instruments and equipment by their own hands. And once they get their degrees, secure jobs and sit on a suitable chair, the interest veers, in most cases, round the paper work and supervisory functions rather than the real down-to-earth problems they and/or their students are involved with. It often comes to our ears that with respect to repairing mechanical equipment the artisans understand and detect the problems much better and more quickly than the engineers. This may not be the whole truth. But even if partially true, it reveals the obtaining gap between the hands and brain in the case of a large number of involved people.

These two can be said to have created an ideological barrier on the way to original thinking and research.

Organisational Barriers

But there was another aspect of the feudal legacy, which remained intact because of the failure to democratise and secularise the society and polity, and which posed an

organisational barrier in the case of *S & T* pursuit. It left a strongly persisting hierarchical mental make up in all spheres of the society including the science and technology affairs. It sustained a boss-and-subordinate relationship among the senior and junior *S & T* research personnel within an institution. It objectively resisted the growth of that broad-minded liberal community feelings among them which is so essential for pursuing creative research, for making purposeful experiments with ideas. In fact, except the relevant departments of most of the universities, in almost all the *S & T* institutes and laboratories what prevails is an undemocratic and bureaucratic environment.

This environment has permeated the entire fabric of the science and technology education and research system from the institute level upto the government level. The picture can be fully grasped from the following facts :

The number of top level policy and decision making authoritative bodies is exceedingly high. While several ministries have their corresponding central research organisations, there are several similar policy making bodies at the same level, for example :

(a) Science Advisory Council to the Prime Minister;
(b) Science Advisory Committee to the Cabinet;
(c) Committee on Science & Technology;
(d) Committee on Organisation of Scientific Research;
(d) National Committee on Science & Technology ;
(f) Department of Science & Technology.

The jurisdiction, function and composition of these six bodies are not identical. But the fact that they overlap in many cases and areas, and thus unnecessarily absorb a greater portion of the relevant budget, is quite obvious.

Just below them, are the following executive organs : (a) Council of Scientific & Industrial Research (CSIR), and University Grants Commission (UGC) under the ministry of Education; (b) Indian Council of Agricultural Research (ICAR) under the ministry of Agriculture; (c) Indian Council of Medical

Research (ICMR) under the ministry of Health; (d) Defence Research and Development Organisation (DRDO) under the ministry of Defence; (e) Atomic Energy Commission, Department of Atomic Energy, etc. all of which have number of research institutes under their control.

At the third layer we have some information collecting and distributing machineries like (a) National Institute for Science Communication (NISCOM), (b) National Institute of Science, Technology and Development Studies (NISTADS), (c) Technology Information Assessment and Forecasting Council (TIFAC), (d) Technology Development Fund (TDF), and (e) Indian National Scientific Documentation Centre (INSDOC)—all for nearly overlapping purposes.

It has to be noted here that all these bodies are formed by nomination, and more often than not they reflect the viewpoints of the governing parties. This of course does not imply that election of members of these bodies would make them automatically any the less bureaucratic. I am also not considering the cases of favouritism and/or corruption that are occasionally associated with functioning of these bodies. The very nature of their formation, composition and functioning invites and preserves bureaucratism. Dr. H. J. Bhaba once commented, "The standard method of planning laboratories and filling posts is often forced on many by the administrative and financial requirements of the government."[16] Later Vikram Sarabhai, who succeeded Bhaba in the Chairman's post of the Atomic Energy Commission, also repeatedly talked of introducing "horizontal control" in the sphere of *S & T* research and development organisations and activities, instead of the "vertical control" practised in the administrative machinery and mechanism.[17]

Prof. A Rahman, who was associated with science-administration for a long time succinctly summed up the Indian situation : "[In] view of the near total dependence of science on the Government and the latter being the major employer of the scientists, the scientists have limited freedom to express themselves on organisational and policy matters and thus have

developed 'personal' instead of 'policy orientation'. The application of hierarchical system to research administration effectively prevents the promotion of initiative and expression of opinions on matters of organisation and policy. Consequently, greater emphasis is placed on being on the right side of the authority, to be able to move up in hierarchy and to be effective. Respect for authority, while it limits free communication amongst the scientists ..... also stills a questioning attitude and healthy scepticism. The dominant tendency is to submit to the decisions taken, however repugnant they might be, and continue to work for promotion."[18]

This bureaucratisation of the Science and Technology organisation is further revealed by the disproportionate size of the administrative personnel compared to the *S & T* personnel among the total R & D manpower of the country. The following table may help to grasp the picture at a glance[19] :

R & D Personnel [as on 1.4.1992]

Sector	Scientists & Engineers	Auxiliary	Administrative	Total
Central Government	39,263	64,433	56,973	1,60,669
PSU Industries	14,126	5,595	2,661	22,382
State Government	19,041	17,549	31,265	67,855
Private Industries	20.130	8,320	4,811	33,261
Private Research Institutes	2,926	2,305	3,950	9,181
Total	95,486	98,202	99,660	2,93,348

This bureaucratised structure and the consequent patriarchal culture have become strong hurdles on the way to original and innovative research activity.

Socio-economic Background

Prof. Rahman wrote a few very significant lines which may throw light on the pros and cons of the Science and Technology Policy in India :"Modern science and technolgy, unlike the science of Pre-World War days, has become an instrument of achieving a set of goals ..... Its missions are set by society in the

context of its political, econonic, social and cultural aspirations. In being linked with society and its goal, it has become subject to considerations other than the growth of knowledge or the internal compulsions of science itself."[20]

Quite correct. In the late fifties, when the first Five-Year Plan was on the way to more or less successful completion, when in 1956 the industrial policy was formulated, Indian economy, or to be more specific, Indian capitalist economy was viewing dreams of rapid growth and development, of rapid industrialisation leading to expansion and diversification of production.

Taking advantage of the then bipolar world situation and bargaining with both the US-camp and the USSR-camp, construction of heavy industries was launched. Side by side, atomic energy and space researches were also undertaken with an eye to all possible future uses —civil as well as military, although, the latter perspective was always covertly pursued. This situation called for a rapid supply of a large number of scientists, engineers and technicians to fill in the jobs in the *S & T* establishments as well as various sectors of the economy. The 1958-Resolution was actually motivated by this socio-economic urge of the time.

Capitalist system leaders today need science and technology only as a production technique and not as the motive force of ideational orientation. On the contrary, they are afraid that thought-provoking *S & T* teaching and research may go farther ahead in remoulding people's mind than merely produce some productive skills. Even in the advanced countries of Europe and America, where secular outlook has got a strong anchor-hold, attempts are afoot from time to time to bring in mystic and spiritualistic forces and ideas to the fore through wide media coverage to overwhelm the average mind. It was therefore no wonder that the Indian state too, while upholding a national science policy and encouraging *S & T* development, took no attempt to secularise and democratise Indian society.

Then, since the mid-eighties, the economic scenario has been showing an irreversible trend of steady decline. Worldwide recession also affected Indian economy. So much so that not to speak of general employment, even the employment of the already available vast army of *S & T* degree holders also has become next to impossible. So from then onwards, there was a distinct policy shift, from encouragement and support of the *S & T* endeavour to gradual restriction of the scope of education and research and withdrawal of financial support.

However, encouragement and support can be proclaimed loudly, but discouragement and withdrawal has to be tactical. So, in course of elaborating the new National Policy of Education 1986 in a Programme of Action, emphasis was laid on "quality" rather than "quantity" : research facilities were restricted through the NET-GATE-SLET type entrance tests although scholarship was enhanced; and, control over research projects and designs were much more centralised. Already scientific researches were taken out from the universities to the specialised institutes. From now on, it became very difficult for the university science departments to get research scholars, and, therefore, fund for maintaining and expanding the existing facilities.

Dr. Mahajan wrote : "The world over, the universities form the core in which most of the scientific research is done ...... Not so in our universities. .... The powers that be have decided that there is no need to do any research in the universitites and what is required are separate research institutes for doing high-quality research. So we have a situation where a few select institutes get an amazingly high percentage of the total Science & Technology funding while a large number of university science departments (what to say of undergraduate colleges) don't even have adequate funds for proper teaching and laboratories. In this argument we are not even referring to the funding for the Department of Space and Department of Atomic Energy."[21]

The new industrial policy statement reflected the crisis situation in the economic front. This required drastic curtailment of all government financial supports to the public utility services like health, education, research, etc. The draft 1993 policy clearly spelt for an increase in private sector investment in *R & D* activities and for self-generation of resources by the *R & D* units themselves. Soon afterwards, the new GATT treaty also imposed a similar programme on the Government of India.

Since the new academic calender year of 1995, the UGC, CSIR and other controlling agencies informed their client institutions of a major fund curtailment in almost all sectors. The situation became so worse that most of the universities and even the premier institutes like the IIT's etc. were compelled to cut down their budget on journals, laboratory equipment, etc. While talking of a perspective plan for the 21st century, of the information revolution and many other fashionable catch-phrases, their real foundation was dealt an injurious blow. The larger portion of the *S & T* budget is funelled into the three strategic areas : space, atomic energy and general defence research. All the other sectors have been put on a semi-starvation budgetary diet.

Way out ?

What is the way out ?

If we seek a sincere answer to this question, we shall have to recognise the necessity of the following tasks and take appropriate programme of action :

(a) To adopt a completely new *S & T* policy through a broad-based democratic process involving all the *S & T* research persons, institutions and organisations;

(b) To democratise the entire structure and function of the *S & T* organisational framework starting from the cabinet upto the institutional level;

(c) to secularise the entire society and polity by introducing a truly secular education policy and pursuing a strictly secular approach in state and civil affairs;

(d) to provide fund to all the existing research projects as required and to increase financial support to all the universities and research institutes for expansion of research facilities;

(e) to create a true spirit of science culture among the *S & T* research personnel.

All these aspects are interrelated parts of an integrated programme. So these should be carried into effect in an integrated way. Any fragmentary approach and attempt will not help to redress the situation.

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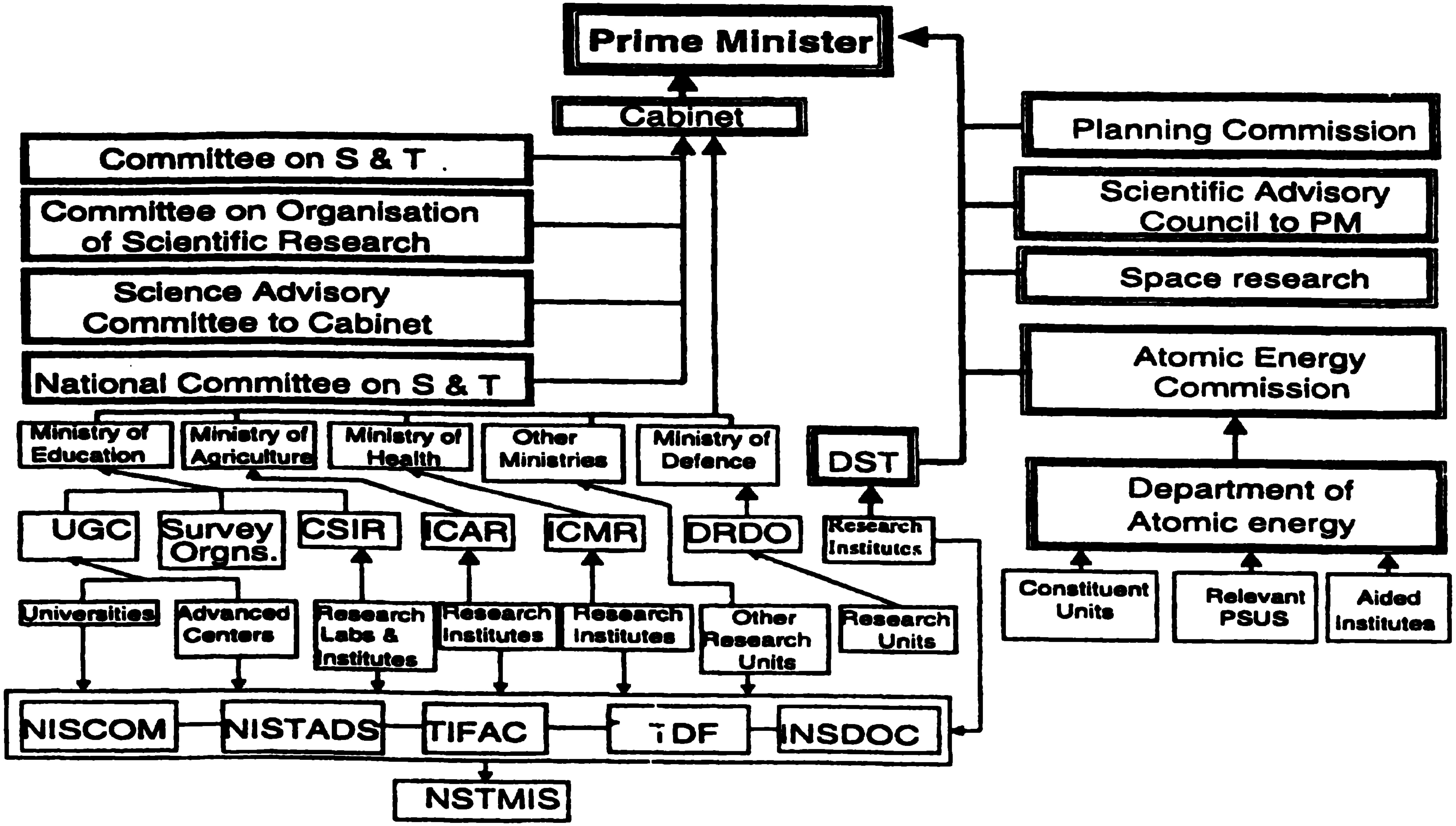
Annexure I : S & T ORGANISATION IN INDIA



II

S & T Research Budget 1998-99 : (Rs. Crores)

Atomic Energy	830.28
Space	1592.34
Oceanography	106.02
Ecology and Environment	485.50
Science and Technology	465.80
Scientific and Industiral	630.37
Biotechnology	112.98
Others	9.79
Total	4261.00

Source : V. K. Gupta — Update Budget ....

1999—2000 Budget :
80% of the R and D budget for
defence, atomic energy & space research

III

R & D Expenditure (%) by objectives (1992-93)

Defence	19.2
Agriculture, forestry & fishing	17.6
Industrial Development	16.4
Space	9.6
Energy	7.9
Transport and Communication	6.7
Health	5.5
Advancement of Knowledge	5.4
Environment	4.6
Others	7.1

Source : A. Rajeswari — [Report for] South Asia;

World Science Report 1996.

IV

R & D Funding (1992-93)		
R & D Institutes :	No.	Fund (Rs.mln)
State Sector	817	5611
Union Sector	412	36012
Universities	210	*
Public Sector	119	6712
Private Sector	1197	8999
Total	2755	57334

* funded by central and/or state govts.

Source : A. Rajeswari — Ibid

V

R & D Personnel (1992)

Sector	Scientists & Engineers	Auxiliary	Adminis- trative	Total
Central Govt.	39263	64433	56973	160669
PSU Industries	14126	5595	2661	22382
State Govt.	19041	17549	31265	67855
Private Sector	20130	8320	4811	33261
Private R. I.	2926	2305	3950	9181
Total	95486	98202	99660	293348

The annual enrolment in S & T disciplines was about 1.4 million, the average annual output of S & T graduates was 0.2 million and total no. of S & T personnel was nearly 4 million.

Source : A. Rajeswari — Ibid.

VI

Education and Research Centres :

* There are 210 Universities including IIT's, ISI's, IISc, and other degree awarding institutes.

* 7513 colleges of which 6400 offer training in general science and arts,
  500 in engineering,
  450 in medicine,
  150 in agriculture,

* 900 polytechnics

Academies = 12
Advanced Societies = 400
Libraries = 850
Archives = 35
Museums = 50

Source : A. Rajeswari - Ibid

VII

Patent Application (1990-96)

Year :	No. Of Patent application
1990-91	1180
1991-92	1293
1992-93	1228
1993-94	1266
1994-95	1741
1995-96	1606
1996-97	1661

Source : V. K. Gupta — Op. cit. ......

SECTION VI

SOCIAL FACTORS IN SCIENCE & TECHNOLOGY

VI - 1

SOCIAL FACTORS IN THE PROMOTION OF SCIENCE AND TECHNOLOGY : A HISTORICAL APPROACH

ARUN KUMAR BISWAS

Abstract

It is presumed that all facts, scientific or historical, are rooted in the principle of causality. Therefore, history of science, in principle, can be and should be investigated in terms of social factors or causes.

We have made a tentative survey of the social factors in the promotion (absence of positive factors causing hindrance) of S & T in (a) ancient and medieval India (b) medieval Europe (c) 17th to 20th century West (Europe and U.S.A.) and (d) post-independence India.

The turning point seems to have arrived in 17th century Europe, when the humanity accepted (for the first time) the idea that institutionalised science is a highly desirable activity, which must be cultivated in a competitive but liberal and pluralistic societal environment. At that turning point (as Joseph Needham has asserted), science ceased to be Indian, Chinese or even European, and became permanently global.

In conclusion, it is submitted that while we can go on elaborating the necessary social factors conducive towards the promotion of S & T, ascertainment of all or sufficient conditions is a difficult task. Particularly, the individual factor or the leadership issue is intractable. Our human society should therefore try to optimise the social conditions, and then hope and wait for the possible emergence of the best leadership in the arena of S & T or any other intellectual domain.

Introduction

History of ideas, intellectual advancements, science and technology (S & T) etc. are all sociological phenomena rooted in the historicity of the social developments. E H Carr beautifully brought out the analogy between history and science.[1] There is no reason to doubt that resembling science, history is also rooted in the principle of causality. Every fact, scientific or historical, can in principle be explained in terms of a system of factors, often inter-related.

The problem is that 'sociological' factors underlying a particular event or discovery are so many in number that these constitute a gigantic omnibus. Even if one scholar compiles such a large number of factors, another scholar can easily point out that a few others have been left out! In mathematical terms we may go on postulating the 'necessary' factors or conditions without which an event or discovery may never occur, but it would be very difficult, if not impossible, to specify the 'sufficient' factors or conditions.

The above statements just made can be amplified by denoting that sociological factors can be infinitely sub-divided into political, economic, intellectual and so on, and that the last one, namely the individual factor defies prediction of any objective kind. Jesus Christ and Newton (if we may take two examples) were aided by their respective social environments in achieving what they did, and therefore a sociological analysis would be useful. But those sociological conditions, could not sufficiently ensure the emergence of the said personalities. Christ and Newton had many cousin brothers and sisters who could not reach their intellectual heights. Therefore environmental and genetic factors taken together do not provide the element of sufficiency. Gautama Buddha suggested the third factor of *Sanskāra* or the qualities of an individual transmigrated soul which provide the spark of excellence. But this is beyond the analytical scope of modern science.

In the present stage of knowledge we are unable to produce artificial intelligence and excellence. But we may historically

survey some of the useful and necessary conditions under which great minds could advance S & T in human history.

There is the burning issue of success and failure in the realms of civilizations, ideas and discoveries. How could Europe succeed in generating modern S & T, and why ancient civilizations of China and India, which had strong scientific traditions, could not? N Sivin thought that the second question, negative in character, is unproductive and as silly as the question : why did one's name not appear in the third page of yesterday's newspaper.[2] We do not accept Sivin's argument, and consider that the negative questions regarding failure and the positive questions (the success stories)are equally useful and should be probed in full earnestness.

The Ancient India

While evaluating the social factors in the development of technology in ancient India we deliberated on the long pre-Harappan traditions which persisted through the Mature phase to the post-Harappan decadence.[3] This early phase of ancient civilisation was characterised by the rise of S & T as well as urbanism.

Gordon Childe, deliberating on the phenomenon of 'urban revolution' in the ancient world, postulated 'ten criteria' which included 'exact and positive sciences such as arithmetic, geometry and astronomy'.[4] Childe could have included material technology as one of the traits of early urbanisation. Though widely quoted, his 'criteria' or indices are 'delineatory rather than explanatory'. His analysis evokes many subsidiary questions. Why did the agricultural surplus not always lead to the formation of cities, and how did some ancient cities (like Mathura) prosper without any agricultural surplus in the immediate neighbourhood? What induces the emergence of a ruling class to dominate over a city? What provides sufficient driving force for artisans to move from the rural to the urban environment?

It appears that a critical measure of trade, cultural and even

military contacts with neighbouring states provide vital stimuli to the growth of civilizations, cities and technologies. This factor has been overlooked by many scholars including Childe. Ecological and military factors (civil war) might have damaged the Harappan civilization, but its collapse was ultimately due to the loss of short-range and long-range trade links.

The phenomenon of the second urbanization in India (beginning in the early part of the first millennium B.C.) was not totally unrelated to the first urbanization despite the contrary claims of the earlier scholars. There were the unmistakable signs of continuity, related to potteries at Bhagwanpura, emergence of iron culture from chalcolithic age at Atranjikhera, sustenance of the arithmetical, geometric and astronomical traditions in the Vedic age. The migrants from the Indus and the Sarasvati Valleys took long time to acclimatise themselves in the Ganga-Yamuna woody areas. After a few centuries, the recovered ecological and political stability once again made the condition ripe for the emergence of power structure, trade contact, new technology and second urbanization in India.

R. S. Sharma's view that discovery of iron resulted in the second urbanization[5] can not be accepted since the widespread use of iron in its carburised form started 5-6 centuries after the discovery of the metal in India (12th century B.C.)

We propose that the emergence of the new technologies and the Iron Age was one amongst many factors underlying second urbanization. Besides, this was a cyclic relationship, urbanization further promoting iron technology. Was there a deeper cause promoting both ? Ghosh accorded priority to the social need/political demand for surplus rather than the capacity to produce the surplus as a result of technological innovations.[6] His argument was in favour of the greater role of a 'power structure' without which a surplus could not appear the moment it is asked for. The megalithic culture in the Peninsular India produced iron and agricultural surplus, and yet no urban tradition. What causes the emergence of a power structure articulating socio-political needs and the growth of S & T?

POPULATION EXPLOSION . IRON AGE

ILLITERACY

SECOND URBANISATION IN INDIA

TWO ILLUSTRATIONS OF CYCLIC CAUSATION

ANCIENT SCIENCE & TECHNOLOGY

URBAN REVOLUTION
&
GROWTH OF CIVILIZATIONS
(GORDON CHILDE)

AGRICULTURAL SURPLUS

TRADE, CULTURAL & MILITARY CONTACTS

EXPANSIONIST URGES

Figure 1

CAUSAL FACTORS
IN EARLY GROWTH OF S & T

Basically it is a psychological drive against complacency and for consolidation of existing resources and distribution mechanism by centralisation; it is also promoted by an expansionist urge to meet shortage of resources by trade or conquest, and even cultural expansionism viz. to propagate one brand of religion or culture. This urge could be articulated in the ancient world as physical/social/political 'needs' only when there were trade and competitive contacts with the neighbouring cultures and states. This reality of psycho-physical situation promoted in the ancient world—and still promotes in the modern world—urbanization, new ideas, revolt against tradition and breakthroughs in new science and technology simultaneously.

Such breakthroughs occurred in Greek science following contact with Persia, Babylon and India, in Indian science as a result of the Greek and Hellenistic influence, and in Arab science following intellectual contacts with Greece, India and China. During the medieval period, the Indians and the Chinese isolated themselves from the outside world and their erstwhile glorious traditions in S & T stagnated. On the other hand, the Japanese people of the 19th century were positively inclined towards the Western science and intellectualism and through this attitude and pursuit, emerged as a modern nation dedicated to S & T.

Prafulla Chandra Ray[7] and Debiprasad Chattopadhyaya[8] in their one-sided views stressed on the internal reason for decline of science in ancient India. Theological obscurantism and casteism were indeed the bane of Hindu intellectual thoughts. But they overshot the mark by painting a negative picture of the Vedic intellectual tradition which after all patronised good science. Uddalak Aruni, Charaka, Susruta, Aryabhat, Varahamihira, Brahmagupta, Bhaskara etc. all subscribed to Brahminic thoughts and yet contributed to scientific progress. Brahminism did nothing to stifle the Jaina and Buddhistic contributions to science, Nagarjuna's contributions to alchemistry and the university traditions at Nalanda etc.

Ray and Chattopadhyaya were strangely silent regarding the barbaric invasions which crippled not only the Hindu Science

in India but also the Arab science at Baghdad. The latter's irreversible decadence was also due to anti-science Muslim fundamentalism, the advent of which in India was bemoaned by Abul Fazl. When the Muslim rulers in India remained oblivious to the glaring evidences of Western S & T displayed in their court, the Hindu traditions of Rasaśāstra, metallurgy and mathematics were prevalent in full swing. Therefore, Ray's and Chattopadhyaya's emphasis on Hindu obscurantism constitute only a small part of the total causes underlying the decline of science in ancient and medieval India.

In our chronological and critical presentation,[3] we tried to establish that Indian S & T prospered in the ancient world, whenever the socio-political factors—such as suitable economic challenges and opportunities, ideological motivation, political stability, contact with the outside world, stimulating but not overwhelming, etc. — were conducive.

Following his masterly and encyclopaedic work on ancient Chinese civilization and science, Joseph Needham asked himself why the modern science did not emerge in China first.

When aristocratic-military feudalism decayed very early in Chinese history, it did not give place, as it did later on in Europe, to capitalist enterprise by the merchants of the great cities, but to a bureaucratic feudalism. A strong central government based on the continuity of an Imperial court needed a gigantic feudal bureaucracy which alone could deal with the problems of a vast territory. Despite many achievements in mathematics, astronomy and technology, the Chinese system was slow in external trade and in the process of learning from the external world.[9]

The Japanese observed the deficiency in the Chinese ethos and readily accepted the Western traditions of external trade, intellectual contact with the outside world and learning the newly emerging S & T from the best sources. Both China as well as India collectively failed to read the writings on the wall, to re-orient their intellectual outlook, which could be done by a small country like Japan in such a short time.

The European Scenario and the Emergence of Modern Science

Before giving due credit to Europe for being the pioneer in innovating modern science, one has to seriously consider why the scientific revolution did not take place in Europe prior to the seventeenth century. There was a long gestation period for four centuries (1300-1700) in Europe before the rudiments of modern science could emerge.

During the twelfth and thirteenth centuries, the Christian Europe learned Greek and Indian science through the Arabs on the one hand, and in the Crusade Wars resisted the military might of the Muslims on the other. It was during this time that the theologians, like Roger Bacon, realised the importance of technological innovations like gunpowder, printing etc. and what science could do to the newly emerging world.

Yet, it was not easy for science to emerge as a distinct institution or profession. In the ancient world, science had served as an appendage to different walks of life : astronomy as part of the priestly role, knowledge of plants as something appropriate to farmers, and that of animals as useful for hunters or herdsmen. But there was no tendency to subsume such knowledge under a rigorous discipline such as science.

Astronomy was polluted by theological debates, astrology and gemmology. The Vedic Śulva Sūtras, the oldest geometrical tradition in India was associated with rituals. In the later centuries, the ritual disappeared, and with it went a mathematical tradition. Periods of scientific decline were much longer than those of scientific growth. So the wonder is not that modern science had not emerged earlier, but that it emerged at all! For nuclear reaction to be self-sustaining in a reactor we need a minimum or threshold level of the activity of the fast neutrons. Similarly the persistence of a social activity such as science, over long period of time such as centuries, always depended upon the threshold level of a chain reaction which was reached for the first time during the seventeenth century Europe.[10] The

European build-up of emancipated knowledge had however started in the thirteenth century under the umbrella of the Church.

The Church had patronised European universities which were similar to the seats of higher learning in India (Nalanda), China and Islamic countries. But there was a difference in Europe. The corporations were authorized by the Church and recognised by the secular ruler. Thus these were not controlled by the king, nor were the subjects taught restricted to the theological. The European student of the thirteenth century no longer went to study with a particular master but at a particular university. Originally the universities concentrated on one branch of study such as law in Bologna, theology and philosophy in Paris and Oxford, medicine in Salerno etc. Gradually diversification started. The tradition of medieval natural science was started at Oxford. During 1400-1700 A.D., the universities at Bologna, Paris, Oxford, Leipzig had nearly 25 professional chairs each, 10-20% of them devoted to science and medicine.

The knowledge base was readily appreciated by the emerging group of capitalists, traders and navigators. Associations between scientists and practical men were not confined to matters with navigation. There was increasing interest in machines, mining, lens grinding, making of watches and other instruments and above all the paper and printing technology. England and the countries in the northern Europe provided a new ethos of technology which aided science and was aided by science. This was a much more promising social base for the marriage of S & T which had never existed in the ancient world.

The rise of technological culture in England and Germany was somehow coincident with the rise of protestantism. The Roman Church was still patronising science so long as it did not challenge the Biblical literature. The Protestant World on the other hand could challenge the old knowledge and rationalise new scientific discoveries with respect for divinity and defiance against the established Church.

It should be noted that the Church still continued to patronise scientific investigations so long as it did not contradict the Bible. The Jesuit priests continued to execute useful astronomical investigations and Galileo's views were not supported in the beginning by the Protestants.

Yet, Galileo provided the death-blow to the theological stranglehold on science, and the leadership in S & T passed irreversibly towards the liberal, pluralistic ethos of Protestantism.

In England, science became involved in Protestant politics in a new and more significant way. The Royal Society (of Science) decided to stay neutral on theological questions; the members agreed not to discuss matters of religion and politics but to restrict themselves dispassionately to the neutral field of science. Under the strain of theological and political debates and the conditions of ideological impasse in 1640, the British scientists found it useful to adopt Baconianism as a strategy of survival. "Thus natural science became the paradigm for the philosophy of an open society."

The crucial difference in the place of science in England as compared with other countries during 1700 was that in England science was *institutionalized* as an autonomous activity separate from the Church and oligarchy. Simultaneously there was in England the concept of social pluralism. The political society was conceived as composed of independent individuals, 'as matter was composed of atoms, and as held in balance by the conflicting forces of the executive, the legislature and the crown.' Since the society did not recognise a single supreme authority, neutral, critical and logical science could now grow in the atmosphere of agnostic pluralism. Ben-David has rightly called the institutionalization of science in 17th century England as the turning point in the history of science.[11] At that time science was still considered to be a potentially dangerous and subversive philosophy in the Catholic Europe. That explains stagnation and decline of powerful Catholic countries like Spain and Portugal. The Dutch and the British gained ascendancy through their Baconian belief in and pursuit of newly emerging S & T.

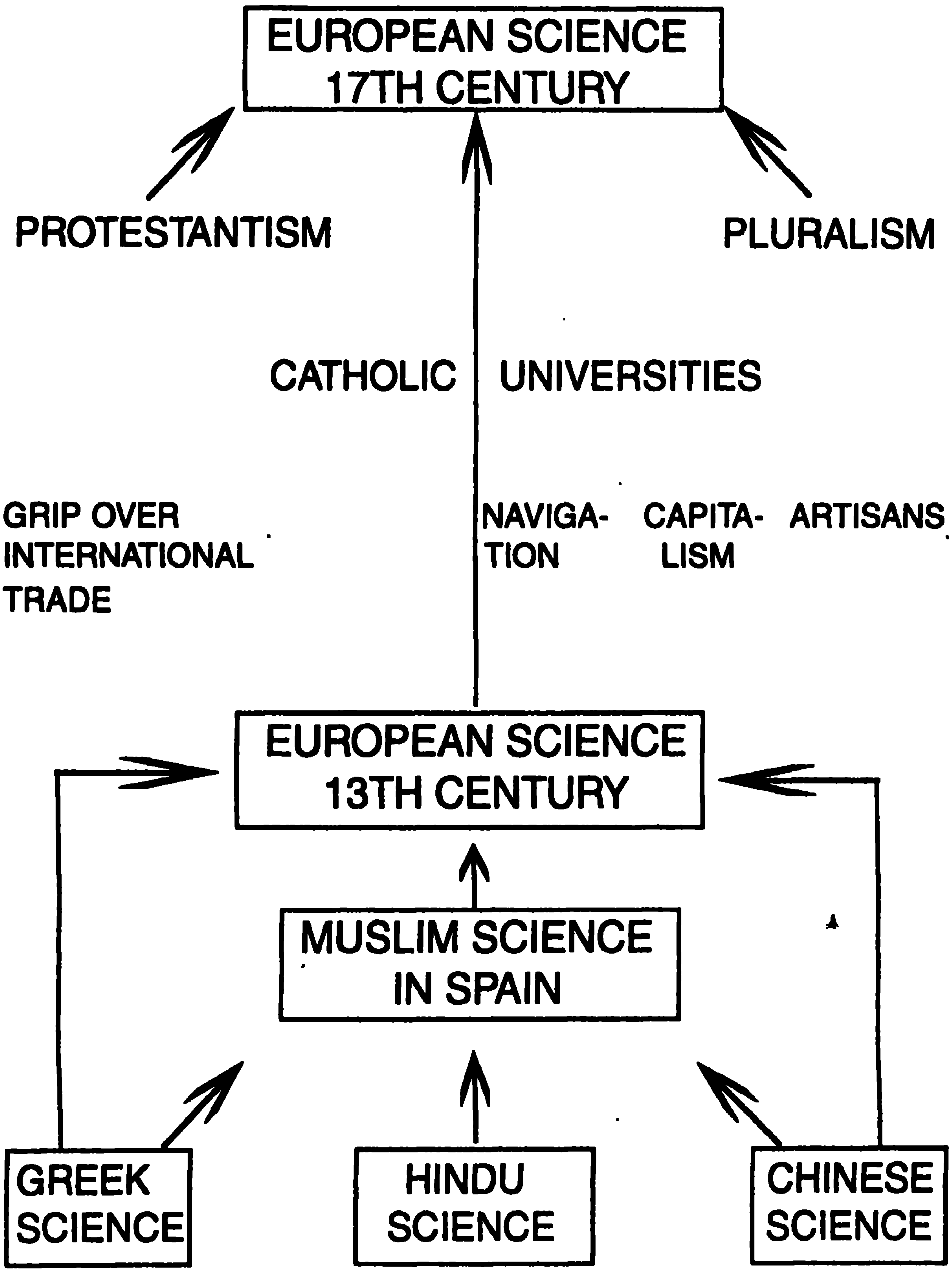


Figure 2.

BIRTH OF MODERN SCIENCE
17TH CENTURY EUROPE

Wave-like Fluctuations in Pluralistic Europe (1700-1900)

The pluralistic or multi-centred ethos in Europe had been evident since the War of the Crusades when the Christian nations were united in fighting the Muslim nations and the Mongols, and yet the states maintained amongst themselves healthy differences and competitiveness. This suited the artisans, technicians and scientists who could move from a less to a more favourable atmosphere for their professions.

With the institutionalization of science in the seventeenth century England, the social interaction and diffusion of ideas amongst the scientists rapidly increased throughout Europe. *Academie des Sciences* established in Paris in 1666, though prompted by the British example, was no imitation of it.

Whereas the British Royal Society was an independent corporation based on mixed membership including ameteurs and scientists, the *Academie* was a sort of elevated scientific civil service under the royal patronage composed of scientists like Descartes, Gassendi, Pascal of high repute. Royal recognition was given on the condition that the critical approach in science would not be extended to the spheres of politics and religion! Although the atmosphere was less liberal, more state patronage helped scientific activities in France.

Scientists and philosophers of England and France were in close intellectual communication with each other, and ideas and discoveries travelled rapidly from one country to the other through correspondence and personal visits. Then there was the diffusion of scientific interest in certain countries of Europe such as northern Italy , Switzerland, Holland and Germany.

During the 18th century and specially for the period 1771 to 1810 British science was decidedly superior to the achievements in any other country. This was partly because Britain was the only large country where upper middle class intellectuals could propagate new ideas of change and reform without the danger of persecution.

In France the key factor was state patronage. Napoleonic policy on science was an extension of the 18th century state patronage to the French science. This explains the great flowering of the scientific activities in France during the period 1800 to 1830. During the 1840s there was the lure of politics and the abandonment of academic careers for careers in politics. Besides there was too much centralisation and bureaucratization in the Central Schools where laboratory research was not given its due recognition. Thus France lost its leadership to Germany.

The contribution of Germany lay in creation of a new tradition : combining the activities of teaching and research in the university departments causing emergence of the university research laboratories.[12] During the first half of the nineteenth century, science was pursued in England and France as amateur lobbies. In France young men passed several irrelevant examinations to secure science-related jobs and occasionally indulge in scientific research as part-time activities. It is under such conditions that Faraday and Lavoisier executed their remarkable discoveries. Scientific research was hardly a part of university curriculum in France and England.

Germany on the other hand gave equal importance to humanities and science in the university structure. In science departments teaching and research were accorded equal priority. As a matter of fact, in view of the rapid proliferation of the universities and science departments in Germany and the consequent personnel requirements, laboratory development for original research and training of young personnel in the art of research was given top priority.

Specially recruited professors like Liebig, the *Privatdozents* (non-professor expert lecturers) and research students initiated a revolution in scientific research for the first time in the world history in an organised fashion. As a result, the laboratories of some German universities became the centers and sometimes virtually the seats of worldwide scientific communities in their respective fields starting about the middle of the 19th century.

The days of solo research, of an ameteur scientist were over. There were some administrative hurdles in German universities and ego problems, but the young researcher of promise could migrate from one to another German university and prosper. Physicists, chemists, historians etc. working at different universities interacted with each other. This phenomenon and the competition among the universities were boons to the intense research tradition in Germany. The growth of institutes of technology and industrial needs in many fields such as aniline dyes, immunizing vaccines gave tremendous boost to applied science and laboratory research tradition in Germany.

The success story of Germany in scientific research was noted and emulated all over the world, not only in England and France but also in the newly advancing countries such as U.S.A. and Japan.

During 1700-1900 the superiority in scientific output passed on from one country in Europe to another. Rainoff quantified the wavelike fluctuations of creative productivity in the development of West European physics.[13] In the 26 five-year periods between 1771 and 1900, Britain made more discoveries in heat, light, magnetism and electricity than France or Germany in eight half-decades almost all during 1771-1810. France took over the leadership during 1815-1830 and then again 1841-1850. Of the 11 half-decades of German superiority, 10 fell between 1851 and 1900. The reasons for the fluctuating superiority have been earlier attributed to improved science policies. The Japanese intelligentsia were very careful observers of this European scenario.[14]

Europe as a whole maintained superiority in scientific activities mainly on account of its pluralistic nature. There was no single centre of excellence, such centres in different countries were many; even a single country like Germany produced many good universities which competed with each other in the areas of S & T. Japan and U.S.A. were eager to learn from this phenomenon of social Darwinism related to competing S & T

research and development centres, and gradually these two countries have become leaders in S & T during the second half of the 20th century.

United States : The 20th Century Leader in Science

During the first half of 20th century, the gradual emergence of U.S.A. as leader of science closely followed the pattern of decadence in Germany. The German universities were becoming highly centralised and even dictatorial. The reputed scientist-professors overlorded the ambitions of younger scientists. With tremendous power vested in them, they often vetoed the growth of new disciplines and sister disciplines. The chemists grudgingly granted some recognition to physical and physiological chemistry; statistics had to fight hard to secure some footing in the big departments of mathematics. The heads of the powerful departments and the institutes often had vested interests in keeping new specialities that arose in their fields as sub-specialities within their own institutes rather than allowing them to become separate chairs with claims for new institutes (or departments).

Besides, science in Germany was an implanted commodity 'thriving as a hothouse flower' without the free air of socio-political enquiry or debate. Intellectual enquiry in Germany had not thrived as part and parcel of the way of life of a middle class of independent people. The German universities professed neutrality in matters of socio-political debates, but were helpless against the intrusion of militaristic jingoism and anti-Semitism within its ranks. Ben-David has rightly argued that it is a futile question to ask whether Germany could have retained leadership in science, if the Nazis had not taken over the country, 'as the universities were part of the system which made the Nazi take-over possible'. The examples of Germany, Japan as well as Russia show that centralised planning can certainly boost the pace of advancements in education, S & T but any loss in the ethos of democratic pluralism and socialistic humanism may ultimately reverse the trend of progress.

In U.S.A. many improvements were made in the university curricula related to S & T.[15] The Graduate Schools or the post graduate educational system fully recognised the twin purpose of original research and acquiring further knowledge from different experts related to the field. Even at the Ph.D. level course-work was essential. In Germany the senior students used to 'learn' from their Professors alone; even the Privatdozents however qualified they might have been could not influence the educational or training policies. In U.S.A. students took courses even outside the department and many teacher-professors made their education broad-based and opened up the possibilities of new inter-disciplinary programmes.

The U.S. professional schools, started as a pragmatic experiment in the land grant colleges during the 1860's, overcame the intellectually constricting influence of the German system. At the undergraduate level, these schools such as M.I.T., John Hopkins Medical University arranged practice schools and rigorous professional training; the post-graduate level education featured research facilities in various applied fields. Thus the dichotomy between basic research and applied professional practice was dispelled. Dispelled also was the notion that basic research was meant for pure sciences only and not in the engineering fields.

New subjects like chemical engineering emerged with full prestige. Statistics came out of Mathematics departments without any rancour or bureaucratic hitch. The British and German universities were rather slow in copying the American model.

The American developments were of course not centrally planned. There were free experimentations in different centres resulting in some failures and several success stories which were then copied.

In a way it was like the states of Europe during 1700-1900 competing with each other. Decentralisation and free competition amongst universities were in full play, and there was the eagerness to learn and borrow from the European system.

The rise of the new universities in U.S.A. was accomplished by a new type of President, who combined the qualities of a statesman and entrepreneur, modifying his policies and university organization in an ever-changing situation. The sub-units of the university were designed to be flexible, autonomous and of sufficient size to perform training and research functions effectively.[15] The departments were egalitarian and not hierarchical as in U.K. or Germany; there were many professors in a single department. The interdisciplinary research centres were not under a single department and never under a single professor (as in Germany).

Such institutions as the senate and faculty assembly do not have much importance in the United States. The constitutional history of the American university is the history of devolution of authority in intellectual and academic matters from the Board of Trustees and the President to the department and its individual members protecting scientist's freedom from interference. The scientist's work has been judged or in a technical sense 'audited' only through the levels of national and international recognition. These developments have rapidly transformed the role of the scientist in U.S.A. The scientists have been less identified with their universities than with their discipline and professional communities. The professional scientific associations in U.S.A. are much more democratic and effective in maintaining standards than their counterparts in Europe. The American Chemical Society for example may de-recognize the Ph.D. degree in chemistry of a U.S. university on account of its poor quality! Thus autonomy goes hand in hand with critical evaluation and competitiveness. The American system has achieved success not only on account of its improved structural or organizational aspects but also due to the liberal attitude of the donors of the fund—business enterprises — which have not encroached on the autonomy of the structure. Such privileges have not been enjoyed by the universities and scientific research organizations in Communist Russia, Nazi Germany or even in state-controlled over-centralized democratic countries. Liberal pluralism has truly functioned and benefitted American sciences

in the universities. The tradition of administration and professionalisation of scientific research has spread from the universities to the industries and non-academic research organizations.

American academic and scientific institutions have thrived because these have deliberately indulged in experimentations, trials and errors, and finally learned from experience. To a large extent this innovating function was and still is absent in Europe and other parts of the world, where much of the efforts of the university corporations have been directed at preventing change and innovation. Paradoxically, nationalization of the university and the scientific research system has over-regimented and crippled the capacity of the system to learn from experience.

Since World War II, U.S.A. has become the leading country in the area of S & T. This has also brought in several crises which affect U.S.A. as well as the rest of the world. There has been a great acceleration of what Weinberg has called 'the force-feeding' of scientific growth[16] of U.S.A. The share of the federal government in total research and development expenditure grew from less than one-quarter in 1940 to more than two-third of the total in 1965. Simultaneously, the Government and big commercial donors have demanded specific kinds of result-oriented research. The cause of autonomous basic research has been seriously eroded. The target seems to be faster and competitive development rather than ecological sanity and total human welfare. As Kuhn has pointed out, the apparent goal of modern science has become 'problem solving' rather then search for truth.[17] The 'problems' to be solved are related to the needs of big corporations and governments and not of the human civilization as a whole.

There is another crisis with the U.S.A. setting the pace and forcing it on other countries, which have found it increasingly difficult to stay in the race. There is increasing exodus of talents and brain-drain from all countries to U.S.A. which is also facing the problem of over-production of graduates and 'unemployable intellectuals'. It is doubtful whether such developments would

be conducive to the harmonious prosperity of the whole mankind and contribute to unfettered growth of S & T.

S & T in Developing Countries

Following his detailed historical and sociological analysis, Ben-David has summed up the three conditions under which the pursuit of science without recurrent moral crises has been possible :

(a) "political conditions that allow social experimentation and pluralism and that contain some methods for comprehensive institutional change and review of change without recourse to violence.

(b) "a permanent attempt to extend scientific thinking to human and social affairs in order to formulate the problems of rapid cognitive and social changes caused by science, and

(c) "the application of the professional norms of the scientist to the social thinker, which imposes the discipline of not discarding existing tradition except on those specific points where there is a logically and empirically superior alternative."[18]

The first of the three conditions is of over-riding importance and if not fulfilled may cause occasional scientific enthusiasm in these societies to be mutilated by 'vogues of antiscientism, romantic irrationality, and even antinomianism threatening the very existence of science.'

Problems in Contemporary Indian Science

We may utilise and extend our sociological analysis to understand and diagnose the ills of the contemporary Indian science. There are many causes for the unsatisfactory progress of Indian science during the 20th Century. We have ascertained some 32 points, which may be grouped under four broad categories.

The first category deals with the past residual problems or hangovers, such as casteism, communalism, mass illiteracy etc. The second category pertains to confusion regarding goals and priorities in modern India. Thirdly, motivational factors have

been lacking and lastly, we notice poor management and leadership in post-independence India. Management has failed to provide to the researchers precise goal and adequate motivation. Bureaucracy has resulted in the growth of S & T more in quantity than quality.

The Hang Overs

1. The religions in India have not been reconciled amongst themselves or with the scientific ethos.
2. Spirituality has so far failed to curb communalism, materialism and corruption. Yet 'the baby should not be thrown away with the bath-water'.
3. If one considers genuine religious pursuit as a 'diversion' (?), we may also reckon serious diversions of resources through consumerism, excessive defence budget, corruption and parallel economy.
4. The intellectual, social and political problems related to casteism stand unresolved and continue to damage the socio-political fabric of the nation.
5. Mass illiteracy continues to haunt science-awareness and accentuates population problem. The literate population is largely alienated from the cultural roots.
6. The science education policy is dismal. The present university curriculum and structure are not conducive for the growth of S & T.
7. The Indian languages have not been utilised as the effective media for scientific instruction.
8. 'Nation' concept is yet to be crystallised. The political stability is threatened by separatism, based on caste, religion and language, population explosion and resource crunch as well as ideological crisis on the issue of socialism/market forces. All these affect the progress of S & T.
9. Threats of invasion, insurgency and terrorism continue.

Items 1-9 illustrate the 'hangover' from the previous phases of

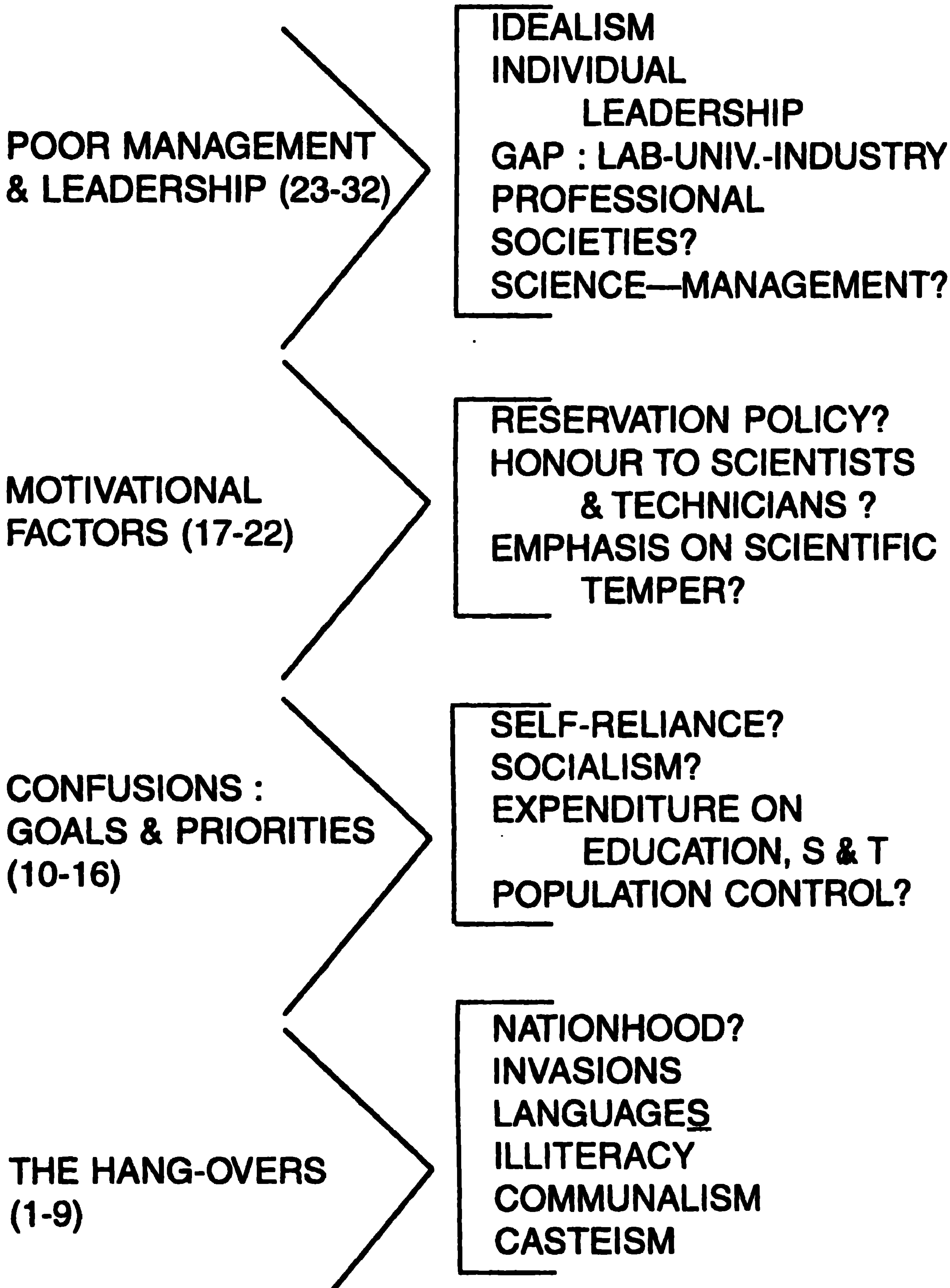


Figure 3

PROBLEMS REGARDING S & T
IN POST-INDEPENDENCE INDIA

the Indian history. There are several new factors in the post-independence scenario.

Confusion Regarding Goals and Priorities

10. S & T policies were outlined, but the hurdles against implementation not anticipated, let alone removed.
11. The priorities have not been clearly fixed.
12. For example, population control has not been given top priority.
13. There was a large backlog of problems : ailing economy, poverty, unemployment, food shortage, security, defence requirements etc. This caused an inertial slow-down of the progress of S & T.
14. Sufficient fund has not been allocated for S & T, education, R & D etc. Even the percentage of GNP invested for S & T continues to be awfully low.
15. The conflict between the needs for attaining technological self-reliance and borrowing technical know-how could not be resolved harmoniously. Finally, the cause of indigenous development has yielded to market liberalisation.
16. Thus, the cause of indigenous S & T and R & D is in doldrums, and we are often importing outdated Western technology at prohibitive cost.

Motivational Factors

17. There has not been sufficient social motivation for S & T. Even Gandhiji was not enthusiastic about rapid industrialisation in India.
18. A full-fledged science movement could not be started at the mass level. Scientific temper could not be built fast enough.
19. The Society and the Government could not provide sufficient incentives for young people to carry on S & T.

20. Prestige accorded to S & T and scientists was not high enough compared to what has been given to the bureaucrats and politicians.
21. The reservation policy in the jobs has become a disincentive for the meritorious.
22. Sufficient emphasis has not been given to the experimental work, machine building, equipment maintenance, support infrastructure, research comradeship etc.

Poor Management and Leadership

23. Management has failed to provide to the researchers precise goal and adequate motivation.
24. Bureaucracy has resulted in the growth of S & T more in quantity rather than quality.
25. Management has failed to bridge the gaps between industries and R & D laboratories, the universities and the laboratories, and even between the laboratories themselves.
26. The professional societies have been weak and subservient to the scientist-politicians.
27. Some successful scientists failed to overcome their ego (example Raman) and to show managerial skill in promoting science (Satyen Bose). Often they quarrelled amongst themselves (Saha and Raman).
28. Some capable scientists have left India for better opportunities and emoluments. They have not paid back the cost of their education, nor has the nation demanded anything from them.
29. The junior scientists have suffered from inconsiderate and incompetent leadership in their organization.
30. Instead of imbibing some idealism, many junior scientists have taken S & T as mere jobs and not as the way of life. They have not been driven by philosophical or intellectual quest, without which originality is impossible.
31. Thus, most scientists of Indian origin, whether residing in

India or abroad have been guided by self-interests rather than patriotism or passion for scientific quest.

32. It seems that half a century after attaining independence, we in India have to plan the development of S & T and society in a fresh and integrated manner. The key components in such a plan should be to instil idealism, to curb counter-idealism and build an egalitarian society. Only then science and society can help each other and ensure a mutual and harmonious growth. One of the imperative targets should be to achieve a negative growth rate of population.

Concluding Remarks

In this article we have historically surveyed the social factors which seem to be *necessary* (may not be sufficient) for sustenance of S & T in different human civilizations. In ancient India, S & T flourished in several eras whenever there were healthy contacts with the external world and the atmospheres were stimulating but not oppressive (internal or external).

Many times science prospered, then stagnated and even declined in Greece, Hindu India, China, Arab countries, and medieval Europe. Only when science was institutionalised as a separate organised activity in the 17th century England that self-sustaining progress of S & T was assured. Ever since then science has progressed through healthy competition, in superior environments, in a liberal and pluralistic society.

The survey of the present Indian scenario (1947 - 2000) indicates that several factors inhibit the desirable growth of S & T in India ; these may be divided under four broad categories : (a) hangover or residual problems, (b) confusion regarding goal or priorities, (c) motivational factors and (d) poor management and leadership. The last category, namely, the issue of leadership seems to be the most important one and the most intractable. As a matter of fact, it is doubtful whether it is fully covered under the 'social' factors. Is the exceptional leader, an outstanding individual, solely a 'social' product ? If so, why

don't we get them in numbers? Terminating his masterly analysis, Ben-David acknowledges :

"The existence of conditions that allow social change is *not a sufficient basis* (italics mine) for the development of vigorous and disciplined social thought. Social conditions do not generate intellectual ability and moral responsibility, they only provide the conditions for their exercise".[19]

We wholly concur with Ben-David and postulate that the leadership issue should not inhibit us from probing the social factors and their inter-relationships in greater depth. Our human society should optimise the social conditions (and then wait) for the emergence of the best leadership; if its emergence can not be totally engineered, at least its inhibition may be prevented.

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CONTRIBUTORS

Arun Kumar Biswas, who has edited this book, taught mineral engineering and metallurgy at the Indian Institute of Technology, Kanpur (1963-95) and is at present (1995-) Professor of History of Science at the Asiatic Society, Calcutta. Professor Biswas is a renowned scholar in the areas of mineral engineering, archaeo-metallurgy, Ramakrishna-Vivekananda Literature and History of Science.

R. L. Brahmachary, former Professor and founder of the Embryology unit of Indian Statistical Institute, Calcutta, has been working on chemical signals in tigers over the last 25 years or so . He is interested in history of science and popularization of science.

Santanu Chacraverti is presently a lecturer in History at Brahmananda Keshab Chandra College, Calcutta. He has published papers in the areas of history of ideas and history of science, and worked on Ramendrasundar Trivedi and Bengal's response to modern western science.

Monindra Mohan Chakrabarty is an eminent educationist and authority on glyceride structure of fats and paints. He had been Vice-Chancellor of Bidhan Chandra Krishi Viswavidyalaya (1978-79), Vice-Chancellor of Jadavpur University (1980-85), President of The Asiatic Society (1992-97) etc. At present, he is the President of the National Council of Education, Bengal.

Sankar Chakrabarty is an eminent electrical and electronic engineer involved in science popularisation work through audio-visual lectures, formation of science clubs, science writing etc.

He is the President, Paschimbanga Vigyan Mancha and Council and an executive committee member of the Department of Science and Technology, Government of West Bengal.

Biswadeb Chatterjee is a Reader in Economics at the Hooghly Mohsin College, West Bengal. He has worked on the theme Public Finance of West Bengal and written a book entitled "Tax Performance in Indian States".

Anirban Das graduated in medicine from the Calcutta University and has a masters in history. Editor of *From the Margins : A Journal of Critical Theory in a post-colonial setting*. Published essays on the historiography and philosophy of science and post-colonial feminist theory. Currently he is working on the interfaces of medicine, history and philosophy.

Kalyan Kumar Dasgupta had studied Applied Physics before starting his career as an Administrator (IAS). He was Managing Director of two major state public undertakings viz., Durgapur Projects Limited and Durgapur Chemicals Limited. He was also Member Secretary of West Bengal Science and Technology Committee.

Nupur Dasgupta, a senior lecturer in the History Department of Javadpur University, has specialised in early Indian History and proto-history of South Asia. She has abiding interest in the history of science and technology and published a monograph on "The Dawn of Technology in Indian Proto-history."

Amitabha Ghosh is a scientist, National Institute of Science, Technology and Development Studies (NISTADS), New Delhi, and an affiliated scholar, Centre for Studies in Social Sciences, Calcutta. He has written a large number of articles related to history of science and technology. In Bengali writes under the pen-name of Siddhartha Ghosh.

Somnath Ghosh is a Professor of Chemistry at the Hooghly Mohsin College, West Bengal. He has worked on Quantum Chemistry and several aspects of History of Science.

Ashish Lahiri is a freelance writer, both in English and Bengali, in the area of history and philosophy of science. He has translated into Bengali J. D. Bernal's *Science in History* and Amartya Sen's *On Interpreting India's Past.* Amongst his original publications in Bengali are *The split in Culture* and the *Philosophy of Science and Karl Popper.*

Late Chanchal Kumar Majumdar (11.8.1938 — 20.6.2000) was an outstanding physicist. He worked at the Tata Institute of Fundamantal Research and then as the Palit Professor of Physics at Calcutta University. He became the Founder-Director of the Satyendranath Bose National Centre for Basic Sciences, Calcutta in 1987. A condensed matter physicist, he is famous for the so-called Majumdar-Ghosh Hamiltonian, now included in text books on advanced studies in magnetism. In statistical mechanics and many-body physics, a significant contribution is the Kohn-Majumdar theorem formulated in collaboration with Walter Kohn who was Majumdar's teacher and is now a Nobel laureate.

After his formal retirement, Majumdar was working as an Emeritus INSA Scientist at the Indian Statistical Institute, Calcutta and conducting research and teaching in physics as well as history of science. He delivered two lectures at The Asiatic Society and was anxious to proof-read his articles but death snatched.him away before he could do this. This monograph is lovingly dedicated to his memory.

Sushil Kumar Mukherjee is the seniormost amongst the contributors and an outstanding chemist and educationist. He had been the Vice-Chancellor of Kalyani and Calcutta Universities. Also Member, National Commission on Agriculture, Fellow of Indian National Science Academy, National Academy of Agricultural Sciences etc.

Ashoke Mukhopadhyay is a science activist, writer and populariser. He is Vice-President of the Breakthrough Science Society and a member of the Editorial Board, *Breakthrough*, a journal on science and society.

Chittarbrata Palit is a Professor of History at the Jadavpur University. He has extensively worked on history of science in India particularly nineteenth and early twentieth century Bengal. Author of a large number of books and articles, he is a member of National Commission on History of Science, New Delhi.

Chandana Roy Chowdhury is a solid state physicist and also a historian of science. She has worked on the life and works of D. M. Bose and is at present a teacher in physics in the Kalna College under Burdwan University.

Smriti Kumar Sarkar, Reader in the Department of History, University of Kalyani, has been working on the various aspects of artisan production, society and technology in India. He has a number of national and international publications on these subjects.

Srabani Sen is a biochemist and also a historian of science. She has worked in the History of science project in The Asiatic Society.

Sunil Sen Sarma is a geologist having retired as the Director of the Geological Survey of India in 1991. He has also served in the research organisation CRESSIDA and the Water and Power Consultancy Services (India) Ltd. as a senior expert in engineering geology for projects in Afghanistan and Sri Lanka.

ABOUT THE EDITOR

PROFESSOR ARUN KUMAR BISWAS, who has edited this book based on an intensive course, had also conceived of the thematic structure of the course and conducted it. He taught mineral engineering and metallurgy at the Indian Institute of Technology, Kanpur (1963-1995) and is at present (1995 -) Professor of History of Science at The Asiatic Society, Calcutta.

Professor Biswas is a renowned scholar in the areas of mineral engineering, archaeo-metallurgy, Ramakrishna-Vivekananda literature and history of science. Author of more than hundred original papers and twelve books, his writings on history of science cover the range from ancient through medieval to the modern period in India. His books such as *Science in India (1969)*, two volumes *Minerals and Metals in Ancient India (1996)*, *Gleanings of the Past and the Science Movement in the Diaries of Drs. Mahendralal and Amritalal Sircar (2000)* etc. have been highly acclaimed by critics.